Bio-fuel / Bio-Diesel

Proposal on Jatropha model farm and business plantation farm for seed and oil production in Bangladesh

By a Jatropha plantation group
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Introduction:

Total electricity generation capacity in Bangladesh is about 3.6 gigawatts of which 94% comes from thermal production and 6% from hydro. This covers only 20% of the total demand of the country. In the rural areas people presently used energy from petrol, diesel and kerosene. A very little people living in the per urban areas use low quality coal for domestic purposes. Presently the prices of the fossil fuels such as petroleum products and coal are very costly. Due to this high price people becoming disinterested to use them as domestic fuel supply, agricultural purposes, etc. Because of the above situations in the supply of fuels, scientists are looking for alternate source of energy, such as solar energy, wind energy, biofuels and biomass. It is estimated that fossil fuel will be used up within 50 years and the scientists and engineers are searching to find out alternative fuel from other sources. This idea of biodiesel came from the German Scientist Rudolf diesel who invented the diesel engines. Commercial production of biodiesel in the United States began in the 1990s.

Presently in some countries are producing oil producing plants to supplement the fuel requirement from biodiesel, specially from jatropha seeds. According to literature review it is found that Jatropha oil is suitable for energy supply for the poor people and it is suitable for domestic lighting in the night, cooking, running small diesel engines etc.

Jatropha curcas is known as wild plant grows in the forest and some farmers in the upland areas uses as hedges. This plant grows well in wide range of soils and humid areas. Bangladesh is a good place for its cultivation. It has many uses like oil for rural energy supply, cake for fish or animal feed, organic fertilizer, bio-pesticides, medicine, soap etc. Jatropha Plantation is seen where rainfall is 500 to 750 mm and also grows in drought prone areas and where rainfall is scanty (Reinhard et al. 2004). Jatropha can bear fruits for 25 years. Jatropha oil is successfully using with small diesel engines in India, Brazil, Madagascar, Thailand, Vietnam, China, Indonesia, and Myanmar (Heller,1996). Average seed yield is around 6 to 15 ton/ha. Seed contains 25 to 37% oil. India is producing bio-diesel commercially from Jatropha Curcas. Besides, many developed countries have active biodiesel program. Currently biodiesel is produced mainly from field crop oils like rapeseed, sunflower etc. in Europe and soybean in USA. Malaysia utilizes palm oil for biodiesel production while in Nicaragua and other African countries it is produced from Jatropha oil.

The free fatty acid (FFA) content should be less than 1%. It was observed that lesser the FFA in oil better is the biodiesel recovery. Different technologies are currently available and used in the industrial production of biodiesel, which is sold under different trademarks. These units are using sunflower oil, soybean oil, rapeseed oil, used-frying oil, Jatropha oil, etc. The main objective is to develop system to cultivate Jatropha commercially and to produce bio-diesel in the country.

Review of Literature:

The aim of this chapter is to discuss the available literatures related to biodiesel production. Very limited works have been done in Bangladesh in this regard. Works relevant to the biodiesel production performed by various researchers are reviewed in this section.

An experiment of biodiesel production from waste cooking oil was conducted by Zhang and Dube (2003). Four different continuous process flow sheets for biodiesel production from virgin vegetable oil or waste cooking oil under alkaline or acidic conditions on a commercial scale were developed. A technological assessment of these four processes was carried out to evaluate their technical benefits and limitations. Analysis showed that the alkali-catalyzed process using virgin vegetable oil as the raw material required the fewest and smallest process equipment units but at a higher raw material cost than the other processes. The use of waste cooking oil to produce biodiesel reduced the raw material cost. The acid-catalyzed process using waste cooking oil proved to be technically feasible with less complexity than the alkali-catalyzed process using waste cooking oil, thereby making it a competitive alternative to commercial biodiesel production by the alkali-catalyzed process.

Antolin *et al.* (2002) studied the optimization of biodiesel production from sunflower oil by transesterification. Taguchi's methodology was chosen for the optimization of the most important variables (temperature conditions, reactants proportion and methods of purification), with the purpose of obtaining a high quality biodiesel that fulfils the European pre-legislation with the maximum process yield. Finally, sunflower methyl esters were characterized to test their properties as fuels in diesel engines, such as viscosity, flash point, cold filter plugging point and acid value. Results showed that biodiesel obtained under the optimum conditions is an excellent substitute for fossil fuels.

Biodiesel Production Methods

Fukuda *et al*. (2001) of Kobe University studied biodiesel fuel production by transesterification of oils. Several processes for biodiesel fuel production have been developed, among which transesterification using alkali-catalysis gives high levels of conversion of triglycerides to their corresponding methyl esters in short reaction times. This process has therefore been widely utilized for biodiesel fuel production in a number of countries. Recently, enzymatic transesterification using lipase has become more attractive for biodiesel fuel production, since the glycerol produced as a by-product can easily be recovered and the purification of fatty acid methyl esters is simple to accomplish. The main hurdle to the commercialization of this system is the cost of lipase production. As a means of reducing the cost, the use of whole cell biocatalysts immobilized within biomass support particles is significantly advantageous since immobilization can be achieved spontaneously during batch cultivation, and in addition, no purification is necessary. The lipase production cost can be further lowered using genetic engineering technology, such as by developing lipases with high levels of expression and/or stability towards methanol. Hence, whole cell biocatalysts appear to have great potential for industrial application.

Peterson and Cook (2002) described the continuous flow biodiesel production. Biodiesel, which consists of the fatty acid esters of simple alcohols, is a potential replacement for a portion of the diesel fuel used in transportation. It is produced from used oil that has been utilized for frying and discarded. It has several advantages. Among these advantages are its classification as a renewable resource, its ability to reduce HC, CO, and CO_2 exhaust emissions, its non-toxic character, and its biodegradability. One of the keys to making biodiesel a viable and profitable energy source is the use of a continuous flow transesterification process to reduce time and cost, thereby increasing production and profit.

Warabi et al. (2004) prepared biodiesel in various supercritical alcohol treatments with methanol, ethanol, 1-propanol, 1-butanol, or 1-octanol to study transesterification of rapeseed oil and alkyl esterification of fatty acid at temperatures of 300 and 350 degrees C. The results showed that in transesterification, the reactivity was greatly correlated to the alcohol: the longer the alkyl chain of alcohol, the longer the reaction treatment. In alkyl esterification of fatty acids, the conversion did not depend on the alcohol type because they had a similar reactivity. Therefore, the selection of alcohol in biodiesel production should be based on consideration of its performance of properties and economics.

Kusdiana and Saka (2004) conducted an experiment to find out the effects of water on biodiesel fuel production by supercritical methanol treatment. In the conventional transesterification of fats/vegetable oils for biodiesel production, free fatty acids and water always produce negative effects, since the presence of free fatty acids and water causes soap formation, consumes catalyst and reduces catalyst effectiveness, all of which result in a low conversion. Therefore, to investigate the effect of water on the yield of methyl esters in transesterification of triglycerides and methyl esterification of fatty acids as treated by catalyst-free supercritical methanol. The presence of water did not have a significant effect on the yield, as complete conversions were always achieved regardless of the content of water. In fact, the present of water at a certain amount could enhance the methyl esters formation. For the vegetable oil containing water, three types of reaction took place; transesterification and hydrolysis of triglycerides and methyl esterification of fatty acids proceeded simultaneously during the treatment to produce a high yield. These results were compared with those of methyl esters prepared by acid and alkaline-catalyzed methods. The finding demonstrated that, by a supercritical methanol approach, crude vegetable oil as well as its wastes could be readily used for biodiesel fuel production in a simple preparation.

Zamora *et al.* (2001) conducted an experiment on the transesterification of *Jatropha curcas* oil. At laboratory level the two-step transesterification process of *Jatropha curcas* oil was optimized, to obtain via methanolysis (KOH and NaOH as catalyst) a product with an ester concentration greater than 99 %.The best results were obtained with 50 % excess of methanol (of the stoichiometric quantity), 1.3 % (of weight) of KOH / NaOH relation, 8:2, and 75 % of the basic solution added at the first and 25 % at the second step. Under the same conditions a two-step process was simulated, working with a mixture of 90 % ester and 10 % *Jatropha curcas* oil. The recirculation of the ester permitted the transformation of a batch process into a continuous one.

Performance of Biodiesel

Studer and Wolfensberger (1992) describe the alternative fuel extracted from biodiesel which can be used in unmodified diesel engines. Compared to petrochemical diesel oil, it offers several advantages. The waste gases contain practically no sulpher, the smoke emission is about 30% lower and the CO_2 emission is more or less compensated by the assimilative process of the plants.

Jori *et al. (*1993) studied two rape methyl esters (RME) and a rapeseed oil mixture was tested as alternatives to diesel fuel in a standard and a turbocharged tractor engine. The bench tests revealed that there was no limitation in the operation of tractors when using the alternative fuels. Engine power was slightly greater using diesel than the other fuels, but the energy consumption and combustion efficiency were lower. Test results were not significantly different for the RME and rapeseed oil fuels.

Peterson and Cook (1999) performed an experiment on the effect of biodiesel feedstock on regulated emissions in chassis dynamometer tests of a pickup truck. Five different vegetable oil esters (coconut oil, used hydrogenated soyabean oil, rapeseed oil, mustard oil, safflower oil, and a methyl ester of soyabean oil from a commercial biodiesel plant), representing a range of iodine numbers from 7.88 to 133, were tested both neat and in 20% biodiesel 80% diesel blends in comparison with low sulfur diesel fuel for the effect on regulated emissions. Lower iodine numbers were correlated with reduced NOx.

Kalligeros *et al.* (2003) investigated biodiesel/marine diesel blends on the performance of a stationary diesel engine. Vegetable oils are produced from numerous oil seed crops. While all vegetable oils have high-energy content, most require some processing to assure safe use in internal combustion engines. Some of these oils already have been evaluated as substitutes for diesel fuels. With the exception of rape seed oil which is the principal raw material for biodiesel fatty acid methyl esters, sunflower oil, corn oil and olive oil, which are abundant in Southern Europe, along with some wastes, such as used frying oils, appear to be attractive candidates for biodiesel production. They also described the fuel consumption and exhaust emissions measurements from a single cylinder, stationary diesel engine. The engine was fueled with pure marine diesel fuel and blends containing two types of biodiesel, at proportions up to 50%. The two types of biodiesel appeared to have equal performance, and irrespective of the raw material used for their production, their addition to the marine diesel fuel improved the particulate matter, unburned hydrocarbons, nitrogen oxide and carbon monoxide emissions.

Schumacher (1999) studied cold flow properties of biodiesel and its blends with diesel fuel. An experimental pour point depressant made by Lubrizol, SVO, was mixed at the rates of 0, 0.1, 0.2, 0.5, 0.75, 1, and 2% by volume with B100, B40, B30, B20, and 100% diesel fuel. Pour point, cloud point, and Centistokes value at 40 ^{0}C were measured and evaluated. The Centistokes value of the biodiesel blends remained above limits established for number 2 diesel fuel when the SVO product was mixed with each blend. Adding the SVO product appeared to increase the Centistokes value of the blends tested. A 20% soya diesel blend that has been treated with the SVO product at 0.75% should provide a safe operating range for most midwest USA communities.

Cost -effective Production of Biodiesel

Neha (2004) studied the cost-effective production and supply of bio-diesel in India. Biodiesel is an upcoming renewable source of energy, which would not only help in controlling the demand and supply of fuel but, in the reduction of pollution. It is simple to use, easy to transport, biodegradable, non-toxic and essentially free from sulpher and aromatics fuel and has about 10% oxygen, which helps it to burn fully. In India, it is prepared from domestic renewable resources i.e., non-edible vegetable oils. India has about 80 million hectares of land that is suitable for the production of non-edible oil-bearing plants. With the help of GIS tools, it is possible to examine the spatial distribution of input resources, in combination with proximity to infrastructure, considered favorable for the production of biodiesel. With the use of 'Remote Sensing', the suitable land area can be selected, for the cultivation of biodiesel-yielding plants. Not only that with the help of GIS it is possible to setup the biodiesel manufacturing plants, near to those areas, which would not only help in reducing transportation costs but would also provide employment to many people.

Effect on Environment

Sun *et al.* (2003) studied the effect of biodiesel on the environment and energy. Biodiesel is a fuel, which can be produced by the chemical process of reacting vegetable oils or animal fats (transesterification). Biodiesel is receiving more attention as an alternative, non-toxic, biodegradable and renewable diesel fuel. Many studies have shown that the properties of biodiesel are very close to that of diesel fuel. Therefore, biodiesel can be used in diesel engine with little or no engine modification. Examining global issues, such as CO_2 emissions, requires a comprehensive life cycle analysis. The biodiesel energy balance, its effect on greenhouse gas emissions, and on the regulated gas emissions and solid waste pollutants were investigated in each step needed to make biodiesel and diesel fuel. They concluded that fossil energy ratio of biodiesel is four times that of petroleum diesel; biodiesel reduces net CO_2 emissions by 78.45% compared to petroleum diesel in the life cycle. On the other hand, the tailpipe emissions of biodiesel such as CO and HC are 46 and 37% lower than that of petroleum diesel, respectively.

Study on *Jatropha curcas*

An exploratory study to detect patterns of variation in flower, fruit and seed production in one-year-old plants of *Jatropha curcas* (Euphorbiaceae) in response to variation in soil moisture and fertility was conducted by Aker (1995) during a 12-month period in Nicaragua. The plant's architecture conforms to Leeuwenberg's model. Flowering tends to be episodic and responds to variation in rainfall. Nutrient deficiency caused growth and reproduction to terminate in smaller plants well before the end of the wet season. Both inflorescence size and the proportion of flowers vary with the vigour of modules. Fruit development is often uneven within an infructescence, the growth of later initiated fruits being delayed until after maturation of earlier fruits.
Grimm and Guharay (2001) studied the pests and beneficial arthropods in *Jatropha curcas*. They have found that the key pest was *Pachycoris klugii* Burmeister (Heteroptera: Scutelleridae), which damages the developing fruit. Second most frequent true bug was *Leptoglossus zonatus* (Dallas) (Het.: Coreidae). Twelve further species of true bugs also fed on physic nut. Other pests included the stem borer *Lagocheirus undatus* (Voet) (Coleoptera: Cerambycidae), grasshoppers, leaf eating beetles and caterpillars as well as leaf hoppers. Among the beneficial insects pollinators, predators and parasitoids are found.

Financial Feasibility of *Jatropha curcas*

Foidl *et al*. (1999) describes the agro-industrial exploitation of *Jatropha curcas.* A variety of products can be produced from the fruits of *Jatropha curcas* in an integrated process. The oil of the *Jatropha* seeds can be used as bio-diesel. The press-cake can be used as fodder (after detoxification), and the glycerol phase of the bio-diesel production process can serve as an insecticide against tick in cattle. The commercial use of by-products has the advantage of hardly any waste being produced.

Staubmann *et al.* (1995) investigated the production of biogas from *Jatropha curcas* seeds press cake. Seeds of the plant *Jatropha curcas* are used for the production of oil. Several methods for oil extraction have been developed. In all processes, about 50 % of the weight of the seeds remains as a press cake containing mainly protein and carbohydrates. Experiments have shown that this residue contains toxic compounds and cannot be used as animal feed without further processing and is a good substrate for biogas production. Biogas formation was studied using a semi-continuous Up flow Anaerobic Sludge Blanket (UASB) reactor, a contact-process and an anaerobic filter each reactor having a total volume of 110 liter. When using an anaerobic filter with *Jatropha curcas* seed cake as a substrate 76 % of the COD was degraded and 1 kg degraded COD yielded 355 liter of biogas containing 70 % methane. **Properties of *Jatropha* Seed** Heller (1996) of International Plant Genetic Resources Institute (IPGRI), Rome measured the moisture content, protein content, oil content, and carbohydrate in 100 g *Jatropha* seed which has been shown in the following table (Table 2.1). It was found that the average oil content of *Jatropha* seed was 32- 40%.

Table 1. Properties of 100 g *Jatropha curcas* seed (%)

Item	Unit of measure	Quantity
Moisture	Grams	6 ~7
Average protein content	Grams	16 ~ 20
Average oil content	Grams	32 ~ 40
Average carbohydrate-rich dry matter	Grams	25 ~ 30
Others (including ash and some valuable alkaloids)	Grams	21 ~ 3

(Source: Heller, 1996)

Objectives:

The main objective of this model farm and business plantation are to produce jatropha seed and oil production in the country.
The specific objectives are as follows:
1. Develop 100 ha Jatropha model farm at Keshoreganj under the district of Mymensingh.
2. Develop Jatropha business plantation farm at Keshoreganj, Brahmaputra char area, Modhupur Forest area, Chapainowabganj, Ambicaganj, Mymensingh, Chandarati, Mymensingh, Lama/kumari/Bandarban and Haluaghat, Hilly area.
3. PRA survey among the farmers, stakeholders and jatropha oil users.
4. Develop different techniques to use jatropha oil, cake and pruning masses efficiently.
5. Establish central processing plant at Joydebpur /Chittagong.
6. Develop extraction techniques among the farmers level.
7. Develop better mother seed and cuttings for high yield.
8. Arrange workshop on jatropha cultivation, extension work periodically.

Land availability:
For the last one month team leader along with his team visited the following areas/regions to ascertain the land availability based on the land system, inundating condition, price of land and interest of stakeholders and users. Table 1 shows the different parameters of the land in the survey areas.

Table 2. Land available in US$/year (1US$= Taka 68.00)

Area	Land available system	Land quality	Land price	Interest of users	Inundating condition
Brahmaputra char area	Lease/buying/self cultivation	Sandy soil	Lease- 300/ha Buying- 3632 /ha Self cultivation- 300/ha (farmer's compensation)	Farmers are interested (native farmers)	Sometimes inundated. Water stands upto 30 cm for few days
Modhupur Forest area	Lease/ self cultivation	Clay soil	Lease-455/ha Self- 230/ha	Interested on leasing	Never inundated
Kashoreganj (Rangamatia)	Lease/Self cultivation	Sandy/ clay soil	Lease-454.044/ha	Interested on leasing	Never inundated Lands are fertile

Hilly + Plain land					
Chapainowabganj	Lease	clay soil	Lease-455/ha	Interested on leasing	Never inundated
Ambicaganj, Mymensingh	Lease	Sandy soil	Lease-460/ha	Interested on leasing	Never inundated
Chandarati, Mymensingh	Lease	Sandy soil	Lease- 450/ha	Interested on leasing	Never inundated
Lama/kumari/Bandarban	Lease	Clay soil (hard)	300/ha	Interested on leasing	Never inundated
Haluaghat, Hilly area	Lease	Sandy soil	300/ha	Interested on leasing	Never inundated

Note on the land system:

1. Brahmaputra area: Normally soil is sandy soil. Soil is suitable to cultivate Jatropha carcus plants. Land topography is such that when high flood comes these areas are inundated. But water stands for 2-3 three weeks. As there is no research work available on the influence of flood water in the jatropha cultivation, some advanced research is necessary and for time being jatropha cultivation in these lands may be avoided.

2. Modhupur Forest area: Modhupur forest area is high forest gland. Tall trees grow there and presently deforestation is on high rate. Deforestated land can be brought under Jatropha cultivation. Soil structure can be made suitable with compost and sandy soil. Besides, soil is very fertile and Jatropha cultivation would be suitable.

3. Kashoreganj(Rangamatia): Presently this place is used for horticultural crops. But farmers are interested to cultivate energy crops. Soil is also suitable for Jatropha cultivation. Monitoring will be easy from Bangladesh Agricultural University, Mymensingh. Appropriate land area can be procured for Jatropha cultivation.
4. Chapainowabganj: It is situated in the northern sides of Bangladesh. Most of the land is flood free. Annual rainfall in this area is the lowest in Bangladesh. In the dry season, soil becomes very hard and in the rainy season soil becomes very soft which protects easy walking and driving vehicle is impossible. Besides, during harvesting in the rainy season it will be not easy due to soft soil condition. Labour requirement would be high.
5. Ambicaganj, Mymensingh: This place is high land having sandy soil condition. Jatropha cultivation will be suitable. Farmers are also interested to grow this new crops. Monitoring will be also easy from BAU, campus.
6. Chandarati, Mymensingh: This place is high having sandy loam in character. Presently vegetables are grown during the rainy season. Jatropha can be cultivated throughout the year and due to soil charater jatropha cultivation would be suitable. Farmers are very innovative to accept new technology and crops like Jatropha cultivation. Required land area could be managed.
7. Lama/kumari/Bandarban: Land is mostly hilly in character and soil is very hard. Land could be made available. The land slope varies from 20 degree to 80 degrees. Jatropha could be cultivated in the land slope between 0 to 25 degrees. But water stress will remain in the soil due to sloping in nature. This will demand frequent watering in the early stage of the plantation. Besides, labour use intensity will increase and the daily labour rate is comparatively higher in comparison to the native lands. Fallow land is available to tune of requirement. Also the cost of land leasing will be lower in comparison to the native lands available in Bangladesh. Yield study should be done as this trees normally grown in plain land in different countries.
8. Haluaghat hilly areas: Free lands are available parallel to the boarder areas between India and Bangladesh. Soil is very hard and clay in character. Water layer is very deep. Irrigation cost will be higher. Enough land area is available (Table 3).

Table 3. Land area obtainable as per survey conducted

Area	Land area obtainable in the first year , ha	Land area obtainable in 10 years time, ha	Comment
Keshoreganj*	100	2,000	Plain land
Brahmaputra char area		1,000	Char land
Modhupur , Forest area		2,000	Forest area
Chapainowabganj		2,000	Plain land
Ambicaganj, Mymensingh		2,000	Plain land
Chandarati, Mymensingh		1000	Char land
Lama/kumari/Bandarban		10,000	Small hills
Haluaghat, Hilly area		10,000	Small hills
Total area obtainable after 10 years of plantation		30,000	

Land area pattern obtainable for the 100 ha model farm and business plantation farm at Rangamatia:
Nearly 200 farmers were assembled in the Rangamatia market. All have shown very good interest to put their land for the Jatropha cultivation. Land size will vary from 0.75 acre to 15 acres. Leasing rate is fixed at 4540.44 US$/ha for a period of 10 years. After 10 years the company will buy the seeds at a suitable price from the farmers. For business plantation farm, land can be leased from the farmers and also can be leased from the government.

Following lands are available as Khashland at the Rangamatia Mouza area:

Table 4. Area available under Khash land at Rangamatia area

Khash Khotian	Dag no.	Mouza	Area to be acquired , acre
2	868	Rangamatia	310
75	872	Rangamatia	556
75	874	Rangamatia	368
75	7	Rangamatia	150
75	566	Rangamatia	120
75	1163	Rangamatia	72
2	378 & 372	Kreshtapur	200
2	875	Rangamatia	450
2	882	Rangamatia	100
2	873	Rangamatia	100

2	1163	Rangamatia	368
2	958	Rangamatia	25
2	951	Rangamatia	20
2	968	Rangamatia	155

Organizational structures and work relationship:

In this project Bangladesh Agricultural University, Jatropha oil company limited and Vitztech global limited will work together. BAU will provide scientific knowledge and technology to the project activities. Jatropha oil company limited will provide field work and selection of land based on the PRA survey carried out by BAU personnel. Vitztech global limited, South Korea will arrange financial aspects required by the project.

Parallel to the project work, Jatropha oil company will arrange social services. For this purpose, two physician will go to the Jatropha growers for examining the physical health of the jatropha cultivators.

Land will be leased where land is cheaper. As the land target is 30,000 ha. This land can not be available in one place. So, land should the leased out in different places. In every places at least 10 ha land area should be leased out for demonstration purpose. This will help in increasing jatropha cultivation area as the farmer will be learned that jatropha cultivation is profitable in comparison to the native and traditional crop production.
Local office will be established in every jatropha growing areas. Office staff will be appointed.

1. Some students will work on the Jatropha cultivation and other different parameters.
2. Interested Jatropha growers will be trained at BAU campus.
3. Extensive travel will be made by the team leader and other project personnel in the Jatropha growing areas to monitor the field activities.
4. Social gathering will be arranged to discuss the problems of the workers, field supervisors.
5. Free medical treatment will be given to the jatropha growing members once in a month to grow interest for jatropha cultivation.

Jatropha cultivation requirement:

Land : This is a vital requirement for the introduction of extensive cultivation of Jatropha in the country. High land is available in different districts of Bangladesh. Approximate 40% land of Barind tract and more than 60% land of Modhupur and Bhawal forest areas are available and mostly they are fallow as because of the recent deforestation occurred in those areas by rapid cutting of the trees by the tribal as well as by the forest department. Besides, land in the northern districts are always available due to drought. The land near to the riversides and char areas can be used for jatropha cultivation. Besides, land in the Bandarban area can be taken under cultivation. Lands in this area are comparatively cheaper. The above table shows the land description for selection criteria.

Jatropha curcas plant: Jatropha is available in Bangladesh but their characteristics and uses are not studied yet. Now time has come to look into the matter for academic study for generating information for jatropha oil as well as the feed for fish and animal. Chemical or physical characteristics of these trees need to be studied for wide scale cultivation in the country.

Seed : Still today Jatropha is not cultivated by the farmers but it is grown in the country as wild plant and is being used for fences in the gardens. These plants should be cultivated and should be classified according to use, seed trial must be done in the farmers field.
Soil: Bangladesh has wide ranges of soil and is suitable to cultivate for any type of tropical and adapted crops. Soil will be tested for suitability of Jatropha cultivation. Preparation of plantation is that pits size is to be maintained at 35cm x 35 cm x 35 cm and, soil characteristics in the pit will be 1/3 sand, 1/3 compost and 1/3 soil.

Cultivation method: Jatropha can be cultivated in wide range of soils. It can grow from seeds as well as from stem cutting. When the stem size is 2cm in diameter, it becomes ready to propagate or multiplication. 30 cm length pieces are cut from the mother plant and planted in the pits in any time of the year. If it is planted in the dry period then little irrigation is required. The plantlet spacing is 1m x 1m. Jatropha can be grown along canals, water streams, boundaries of crop fields, along the roads, along railway lines. In short, the less fertile lands are suitable for this plant. Once the roots penetrate deeper, Jatropha can tolerate acidic or saline soils. It's growth can be accelerated by using compost fertilizer, cow dung and other chemical fertilizers. Some micronutrients are also helpful in improving productivity. The pH of soil should be 5.5 to 6.5. Bangladesh is an ideal place for the cultivation of Jatropha Curcas.

Expeller for Jatropha: Many types of expeller is available in different countries of the world, such as in India, South American countries. This machine can be directly imported into the country or can be developed here for experimental purpose. Our old mustard expellers with little modification can be used for Jatropha oil extraction. Oil extractor and refiner is available in the international market and the price is around 30000$. This machine is suitable for commercial production. Manually operated small unit is also available and it can be locally manufactured.

Pit Preparation: The size of the pits varies from 50 cm * 50 cm. The soil was taken out and kept open for one week to sundry. While refilling the pits stones and boulders are to ber removed and filled with 1/3 normal soil, 1/3 sand and 1/3 compost.

Propagation Method: There are various methods of propagation of *Jatropha*, either generative or vegetative. Direct seeding has low survival rates. Only under good conditions of a well prepared soil and optimal moisture content and using more seeds per hole direct seeding can be successful. Good survival rates (>90 %) are normally given with direct planting of cuttings and the transplanting methods (Heler,1996). Direct planting method will be used for the plantation purpose in this project.

Fig1. Cutting for *Jatropha* plantation

Intercultural Operations:

Fertilizing: About 2 kgs of organic manure along with fertilizers containing N, P and K will be mixed and applied at the time of planting. An Admixture of 20 gms of urea, 120 gms of SSP and 16 gms of MoP will be applied after the establishment of the plant. The plants will respond well to addition of small quantities of calcium, magnesium and sulpher. The plant does well when rich organic nutrition will be provided.

Pruning: The plants need to produce side shoots for maximum sprouting and maximum flowers and seed. Pruning will be done during the end of second year when the branches reached at a height of 40 - 60 cm to ensure the tree grows into proper shape and size. The top of the plant should be cut off cleanly to produce 8 –12 side branches. It is considered as a good practice. Every year branches grow near the base, and these should be removed and replanted elsewhere. In order to facilitate the harvesting, it is suggested to keep the tree less than 2 meter height.

Hoeing & Weeding: Hoeing and weeding at least twice a year is necessary, especially during the establishment period. Weeding will be accomplished as and whenever necessary to keep the plant free from weeds for better soil aeration and to break the crust. It also helped in soil moisture conservation.

Fig 2. Hoeing and weeding

Harvesting: The flowering in *Jatropha* depends upon the location and agro climatic conditions and fruits mature in two to four months. Flowering is started in the middle of May and harvesting will be started at July every year when the fruits showed symptoms of characteristics color, size and maturity. The fruits were collected from the branch by hand picking. The harvested fruits should be kept in dry place.

Processing and Handling: After collection of the fruits they required to be dried until all the fruits have opened. Direct sun has a negative effect on seed viability and seeds should be dried in the shade. The seeds to be dried after they were separated from the fruits and cleaned.

Storage : Seeds needs to be sorted as good, medium and poor quality. Good seeds are used for plantation while others are used for extracting oil. Seeds should not be stored in damp and dark place. It should be stored in air tight containers.

BAU experience:

Jatropha was planted in sandy loam at BAU Farm (Fig. 3).

Fig.3 Jatropha plants at BAU Farm

a. Oil extractor b. Oil filtering process

Fig.4. (a) Oil extractor and (b) filtering process manufactured in Mymensingh

Recently 660 plants are planted in the BAU farm for demonstration purpose. The plant is growing well and flowering is seen in the Fig. 5 These plants have been collected from Northern district of Bangladesh and also from Hilly areas. The plant is still wild and need more time for its adaptation through demonstration in the native field.

Table 5 shows the first yield trial at BAU farm. Literature shows that Jatropha seeds contain 25 to 37 % oil. From this information the production of Jatropha oil will be 1500 -1600 liter/ha-year and the present market value will be around Tk. 46000 - 47000 which is roughly two times of paddy cultivation. Besides, Jatropha grows very fast and it can supply biomass to the growers and Jatropha can be grown in low quality soil. After jatropha oil extraction, cake is an excellent source of plant nutrients. Fig 6 describes the recently harvested Jatropha fruit, seed and kernel. The physical properties of the jatropha seeds is shown in Table 6.

a. Jatropha plant b. Jatropha flower c.Jatropha fruit

Fig.5. Jatropha Curcas at BAU campus (Islam, 2006)

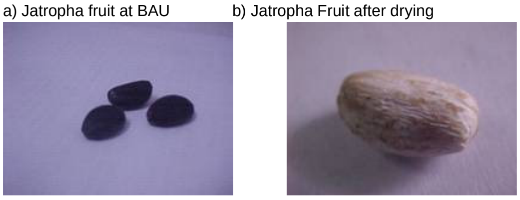
Table 5. Performance of Jatropha curcas plant at BAU farm

Plant No.	No. of branch	No of Male flower in each branch (%)	No. of Female flower in each branch(%)	No. of fruit in each branch (%)	No. of seed in each fruit	Estimated seed production (ton/ha)
1	24	96	4	3-4	1-3	5-6
2	19	94	6	4-5	1-4	5-7
3	18	95	5	4-5	1-2	4-5

Table 6. Physical properties of Jatropha seeds

Sample number	Weight of seed, g	Number of seed	**Volume of seed, cm^3**	Bulk density, g/cc
1	300.2	590	975	0.307897
2	169.7	322	510	0.332745
3	215.2	418	680	0.316471
4	107.5	227	355	0.302817
5	94.3	171	280	0.336786
6	82	165	250	0.328
7	183.1	381	600	0.305167
8	283.9	584	960	0.295729
9	77.6	158	225	0.344889
10	249.9	493	800	0.312375
Mean	176.34	350.9	563.5	0.318288
STD	84.35411	169.1235	286.1531	0.0164

a) Jatropha fruit at BAU b) Jatropha Fruit after drying



c) Jatropha seed from one fruit d) Kernel of Jatropha seed

Fig. 3. Jatropha fruit, seed and kernel

Potential characteristics of Jatropha oil:

Jatropha oil production from Jatropha Curcas using screw type expeller is using in many countries of the world. Jatropha oil has the similar characteristics of the fossil diesel fuel and it can be directly used to diesel engines. Table 4 shows the characteristics of jatropha oil and comparison with fossil diesel. Jatropha oil will not pollute the air during the engine operation as it contains low amount of sulphur. Besides, it is safe in storage as it has flash point higher than the fossil diesel fuel. Also its viscosity is slightly lower than the fossil diesel which is a good criteria for smooth flow of the oil through the injector.

Table.7 Characteristics of Bio-diesel and comparison with fossil diesel

Variable	Jatropha oil	European standard
Density @ 15℃ (kg/m3)	884	860-900
Viscosity at 40℃ (mm2/s)	4.9	5-5.0
Flash point (℃)	169	> 101
Cetane number	58-62	>51
Phosphorus (mg/kg)	<1	<10
Sulphur	<1	<10

Oil extraction by chemical methods (Cold percolation method for measuring the oil percentage): The flow diagram of the jatropha oil production method is shown in Fig.7.

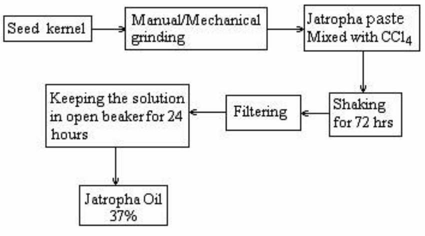


Fig. 7 Flow diagram of the chemical method

With this method, about 37 percent oil can be recovered. The operating cost is much higher.

Oil extraction by Mechanical method:

Traditional and locally made oil expeller is used to produce Jatropha oil. Jatropha oil extraction from this type of expeller is around 15% to 20%. But if we can make some modification on the expeller then higher recovery is possible.

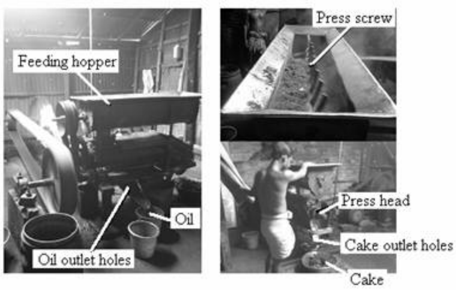


Fig.8. Locally made oil expeller is in operation

Fig.8 shows that locally made oil expeller is using for producing Jatropha oil in Mymensingh. The x -sectional view of this expeller and flow diagram of the operation are shown in Fig.9. Average cost of this type of expeller in the local market is around 60 to 70 thousand taka.

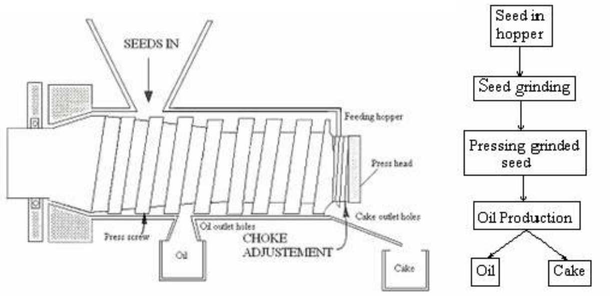


Fig.9 Sectional view of the locally made oil expeller and flow diagram of oil production process

Oil Extraction from Jatropha Seed:

Oil can be extracted from the seeds by heat, solvents or by pressure. Extraction by heat is not used commercially for vegetable oils. The oil from *Jatropha* seeds can be extracted by three different methods. These are mechanical extraction using a screw press, solvent extraction and an intermittent extraction technique viz. soxhlet extraction, cold percolation.

Chemical Method:

Oil content in *Jatropha* seed was determined by cold percolation method. The word cold in this context means no heat was applied and extraction occurs at room temperature.

Preparation of Seeds:

The ripe fruits were plucked from the trees and the seeds were sun dried. They were decorticated manually or by decorticator. To prepare the seeds for oil extraction, they should be solar heated for several hours or roasted for 10 minutes. The seeds should not be overheated. The process breaks down the cells containing the oil. The heat also liquefies the oil, improves the extraction process.

Equipment and Chemicals Used:

Agate mortar and pestle, percolator and sintered glass funnel, 20 ml air tight plastic bottle, 100 ml beaker, sand bath, Mattler balance, Sodium sulphate (Na_2SO_4), Carbon tetrachloride (CCl_4) and finally crushed glass powder.

Procedure of small experiment:

0.3g of *Jatropha* seed powder with 2g of glass powder and Na_2SO_4 was taken into a mortar. The mixture was grinded to a fine stage. Then 10 ml of CCl_4 was put into the mortar to make a solution. The solution was then taken in a 20 ml vial. The volume of the solution was made 20 ml by adding CCl_4. The vial was shaken over night by using a shaker. The solution was then filtered with the help of sintered glass funnel and percolator. The filtrate was collected in a pre weighted beaker with two glass ball. The beaker containing filtrate (oil + CCl_4) with two glass ball was placed on a sand bath for evaporation of CCl_4. Evaporation was done at 60-70° C. After the evaporation the beaker containing oil was kept in a dessicator for cooling. Finally the beaker with oil and glass ball was weighed accurately.

Fig 10. Cold percolation method

Calculation of Oil Content:

$$\% \text{ of oil} = \frac{(w_2 - w_1) \times 100}{w}$$

Where,

w = weight of sample, g

w_1= weight of the beaker, g

w_2 = weight of the beaker with oil, g

oil = (w_2 - w_1), g

Mechanical Method:

Process of Oil Extraction:

Traditional and local made oil expeller was used to produce *Jatropha* oil. This expeller is also used to produce oil from mustards, sunflower or nuts. Seeds are poured into the expeller through the hopper. The expellers have a rotating screw inside a horizontal cylinder that is capped at one end. The screw forces the seeds or nuts through the cylinder, gradually increasing the pressure. The last screw is set in such a way that the face is opposite to the rest of the screws. Due to this opposite pressure oil exterted from the seeds. The oil escapes from the cylinder through small holes or slots, and the press cake emerges from the end of the cylinder. Oil comes out from the oil outlet hole and the cake can be collected from the cake outlet hole.

Plant Growth:

Like all perennial plants, *Jatropha* displays vigorous growth in youth that tails off gradually towards maturity. Plant height is one of the important parameters which is positively correlated with the yield of fruit. The average growth has also been shown in the bar chat in Fig. 11. Growth rate was increasing at the increasing rate from 60 to 120 days and increasing at the decreasing rate 150 to 300 days. The plant height was desired to be kept within 150-160 cm so that harvesting of the fruits would be easy. It has been found that after 300 days or 10 months of plantation the average height of the plants reached around 162 cm. It has also been observed that in the first six months the plant growth rate was higher than that in the rest of the four months.

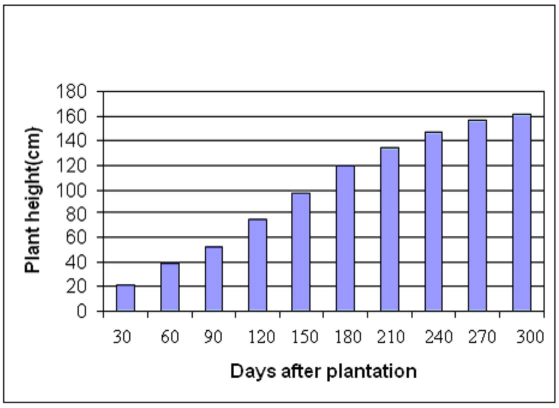


Fig.11. Average plant growth

Crop Density:

The average number of branches of a plant was around 21. At different height from the ground level, the maximum perimeter of the plants was at 90 cm height. The canopy structure of a *Jatropha* plant has been shown in Fig. 12.

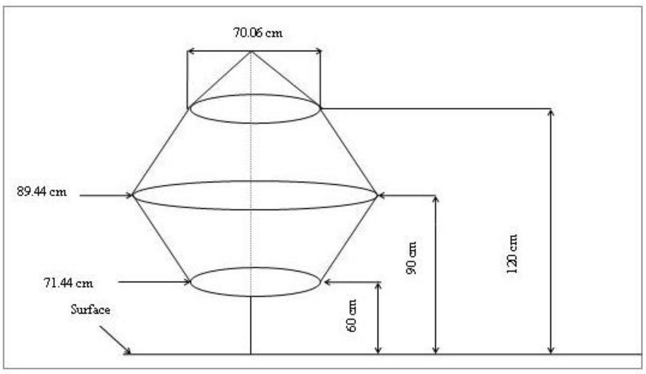


Fig.12. Plant canopy structure

Considering the shape of the plants as a ellipse rotated around its major axis, the average diameter at 90 cm height was 89.44 cm. If the length of the plot is 10m and width is 5m then total number of plant can be accommodated in a row is 10 m / .895 m = 11.17 or 11 and the number of row will be 5m / 0.894 m = 5.48 or 5. So in a 10m * 5m or 50 m^2 plot the number of plant can be planted is 11 * 5 = 55 as shown in Fig. 13. According to this in one hectare land the approximate number of plants can be planted is

11,000. If intercropping is done then minimum 2 meters distance between each plant should be kept. Based on this approximately 2500 plants can be accommodated in one hectare of land.

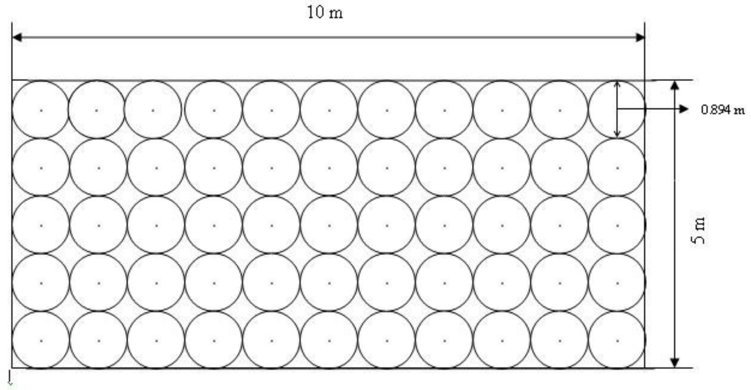


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Fig. 13.Plant density in a 10m * 5m plot

Number of Flower and Fruit per Plant:

After five months of plantation flowers came out and the average number of male flower in each plant was 713.9 and female flower was 40.4 during the first harvest. The ratio of male and female flower was almost 18:1. Flowers were found again after five months of the first harvest. During the second harvest the average number of male flower in each plant was 1619.2 and female flower was 95.6 and the ratio of male and female flower was 17:1. The yield of fruit depends on the number of female flower. More number of female flowers means more yields.

Number of flowers per plant:

It has been observed that the number of female flower increased 137% during the second flowering than the first flowering. Table 8 shows the total number of fruits harvested from each plant during the first and second harvest. The average number of fruit collected from a plant was 34.3 in the first harvest and 82.4 in the second harvest. Fruiting increased almost 140% during the second harvest.

Table 8. Number of Fruits per Plant

Plant no.	During the 1st harvest	During the 2nd harvest
1	25	70
2	26	66
3	25	75
4	36	101
5	30	70
6	55	126
7	35	95
8	50	81
9	31	75
10	30	65
Average	34.3	82.4

Physical Characteristics *Jatropha* Seed

The shape of the *Jatropha* seed is oval, flattish on one surface, rounded on the opposite, each side presenting a slight elevation, running lengthwise. It has a fissured testa of a blackish color. The maximum diameter of the seed was around 9 to 10 mm. *Jatropha* seeds were about 17 mm long and average weight of a seed was 0.76 g (Table 9).

Table 9. Physical characteristics of *Jatropha* seed

Seed from plant no.	Diameter, mm	Length(L), mm	Weight, g
1	10	18.5	0.88
2	9.5	16.7	0.72
3	9.3	17.4	0.78
4	9.5	18.5	0.90
5	9.3	16.5	0.73
6	10.2	15.6	0.66
7	9.5	17.5	0.82
8	9.7	17.3	0.77
9	9.3	16	0.61
10	9.5	16.5	0.74
Average	9.58	17.05	0.76
STD	0.39	0.97	0.090
CV (%)	3.56	5.71	11.89

Yields per Plant:

To withstand extreme drought conditions, *Jatropha* plant sheds leaves to conserve moisture, which results in reduced growth. Although *Jatropha* grows in soils with low fertility and alkalinity, better yields can be obtained on poor quality soils if fertilizers containing small amounts of nutrients viz. calcium, magnesium and sulfur are used. The plant has an average life with effective yield up to 50 years and reach it's full capacity production from the 3 rd year onwards (Joachim, 1996). Considering the average weight of the seed as 0.76 g (Table 9), total seed weight of individual plant was calculated for the 1st and 2nd harvest (Table 10). It was found that from 1st to the 2nd harvest the total seed weight increased around 144%.

Table 10. Seed yield per plant

Plant no	During 1st flowering	During 2nd flowering

	Number of fruits	Number of seeds	Total seed weight plant^{-1}, g	Number of fruits	Number of seeds	Total seed weight plant^{-1}, g
1	25	62	47.12	70	181	137.56
2	26	64	48.64	66	172	130.72
3	25	61	46.36	75	190	144.4
4	36	90	68.4	101	259	196.84
5	30	74	56.24	70	180	136.8
6	55	140	106.4	126	311	236.36
7	35	89	67.64	95	242	183.92
8	50	128	97.28	81	206	156.56
9	31	77	58.52	75	188	142.88
10	30	76	57.76	65	168	127.68
Avg.	34.3	86.1	65.436	82.4	209.7	159.372
STD	10.37	27.32	20.76	19.43	46.52	35.35
CV %	30.24	31.72	31.73	23.58	22.18	22.18

Table 11. Average oil percentage in *Jatropha* seed

Sample Number	Sample weight, (g), w	Wt. of empty beaker with glass ball(g), w_1	Wt. of w_1 + oil, (g), w_2	w_2-w_1 or oil (g), w_3	Seed cake (g), w - w_3	Oil (%)	Seed cake (%)
1	0.32	40.88	41.01	0.13	0.20	37.71	62.28
2	0.36	49.34	49.46	0.12	0.23	35.56	64.43
3	0.35	40.59	40.72	0.13	0.23	35.27	64.73
4	0.33	29.97	30.10	0.13	0.21	36.82	63.18
Average	34	40.19	40.32	0.13	0.22	36.34	63.66

The estimated biodiesel production per hectare will be 654 * 363.4 = 237663.6 g or 237.66 kg during the 1st harvest and 1593 * 363.4 = 578896.2 g or 578.896 kg during the 2nd harvest. So biodiesel production increases up to 144% from 1st to 2nd harvest.

Economic Analysis:

Jatropha cultivation makes up for a highly rewarding enterprise. It requires minimal investment, inputs and maintenance. The plant comes into bearing from first year onwards and stabilizes by 3rd year. It gives yield up to 45-50 years. Normally, the yield from one hectare plantation is in the range of 2000 - 3000 Kg, depending upon the local climatic and hydro-geological conditions. The yield is also influenced by the planting material and management practices (Henning, 2004).

Table 12. Projected annual yield of *Jatropha* seed per plant

Year	*Jatropha* seed yield plant^{-1}, kg		
	Low	Normal	High
1	0.10	0.25	0.40
2	0.50	1.00	1.50
3	0.75	1.25	1.75
4	0.90	1.75	2.25
5 & onwards	1.10	2.00	2.75

Based on Table 9 considering the annual normal production rate of *Jatropha* seed per plant and also considering the price @ Tk. 7.50 per kg, from one hectare of land with 10,000 plants the estimated income has been shown in Table 8. It has been observed that the trend of yield increases from the first to the fifth year. After the fifth year the yield of seed would be almost the same which is normally 2 kg per plant.

Table 13. Estimated incomes per hectare of *Jatropha* cultivation

Year	No. of plants in one hectare (X_1)	Price per kg (X_2), Tk.	Annual seed yield plant^{-1} (X_3), kg	Total quantity of seed ($X_4 = X_1 * X_3$), kg	Total income, ($X_5 = X_2 * X_4$), Tk.
1	10000	7.5	**0.25**	2500	18,750
2	10000	7.5	**1.00**	10000	75,000
3	10000	7.5	**1.25**	12500	93,750
4	10000	7.5	**1.75**	17500	1,31,250
5	10000	7.5	**2.00**	20000	1,50,000

Table14. Economics of *Jatropha* cultivation in one hectare land

	Year				
	1	2	3	4	5
Cost	59,868	15,188.25	5,000	5,000	5,000
Benefits	18,750	75,000	93,750	131250	150000
Net Benefit	-41,118	59,822.75	88,750	1,26,250	1,45,000
Benefit/Cost	0.313	4.94	18.75	26.25	30

It was found that the net benefit of the farmer was negative in the first year. From the second year the return would increase up to nearly Tk.60,000 and it increases gradually up to the fifth year. After five years, the return becomes stabilized and the cost becomes very low. So farmers will receive a handsome amount of profit after that period.

SEED: Better quality seed with dwarf in nature should be procured from Jatropha growing countries to obtain better yield.

Table15. Activity Chart for 20 years of business plantation (Target 20,000 hector

Year/ Activity	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Land collection																				
Land development																				
Plantation																				
Inter Cultural operations																				
Irrigation																				
Fertilizer application																				
Pruning																				
Harvesting																				
Fruits & seed processing																				
Oil extraction																				

Bu es

Ca pro

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in contact with the jatropha growers and provide technical assistance to farmers and other inputs.

Land area target: 100 ha model farm

The team visited several places and discussed the local leaders and farmers regarding the possibilities of managing land for the cultivation of Jatropha. The team also visited local government and rural development offices and discussed with the superintendent engineer, roads and high ways. All assured the team that Land can be obtained in the road sides. JOCL (Jatropha oil company limited) will have to pay cultivation costs as seed/seedlings, fertilizer, pesticides, labour cost etc and some compensation to the farmers as they would not be able to cultivate the traditional crops in their land due to the cultivation of jatropha. JOCL thinks that leasing system would be better option for jatropha cultivation in Bangladesh. Examples of calculation of cost are shown below:

a. Land cost= 1839US$/acre*2.47 acre/ha*100ha= 454233 US$ for ten years period
b. Budget estimation for the 100 ha model farm operation (first year):

1. Seedlings (age - 2 month) cost: 3000seedlings/ha* 100ha* 0.052 US$/seedling=US$15600. (This requires polythene bag, soil, sand, compost/fertilizer cost and their carrying cost and labour)
2. Reclamation and cultivation cost: US$2.21/day*50 day/ha*100 ha= US$11050. (This requires initial breaking of the soil, making pits etc)
3. Fertilizing and irrigation: US$90/ha*100ha=US$ 9000 .(As a starter gift, mixed with the top soil about 0.025 kg single super phosphate should be added in each pit. Fertilizer application @ 45(1:1:1) gm per plant having N.P.K. should be repeated at the start of rainy season every year from 2nd year and onwards).
4. Intercultural operations: US$2.21/day*30day/ha*100ha= US$6630. (Pruning and care: Early in the next rainy season, the one year old plant should be cut back with a sharp cutter at a height of about 0.5m to 0.6m from ground level. Plant should be allowed to grow and put on side branches up to the beginning of the rainy season of the 2nd year. Besides, some training to the plant is needed to be done for proper solar energy penetration into the Jatropha canopy. This will enhance more seed production and further requirement of periodical pruning should be decided on the basis of further experiments for obtaining optimum production of seed.)
5. Harvesting and drying fruits: US$2.21/day*15 day/ha*100ha= US$3315.
6. Seed separation from fruit and seed drying: US$2.21/day* 10 day/ha*100ha= US$2210.
7. Cost of jute sack for packaging of goods: US$1.00/sack* 1000sack= US$1000.
8. Trucking cost (for transporting from farmers house and finally to central plant: US$8/T* 5T/ha*100ha= US$4000.
9. Sand and compost: US$ 2360.
10. Misc. cost: US&4411. (This cost involves which are not mentioned above)

Staff cost:

1. Team leader (For Dr. Md. Daulat Hussain): US$1323/month*12= US$15876.
2. Honorarium for company chairman: US$ 2206/year
3. Manager =US$294/month*12=US$3528.
4. Field supervisor, 4 persons = US$221/month*12*4= US$10608. (This include BAU lecturers and experienced persons from field)
5. Driver, 1 = US$100/month*12 month= US$1200.
6. Office attendant, 1= US$50/month*12 month= US$600.
7. Two permanent labour for the nursery= US$50/month*2*12 month= US$1200 (as nursery worker and guard)

Establishment of a permanent nursery:

1. Boundary and land development: US$3088.
2. Simple house construction with accessories: 30m* 5m= US$9411.

Travel and transportation cost:

5 visits/month*12 month* US$ 50/visit= US$3000.
Per diem= US$22*3*12*5= US$3960.
Cost of one Pick – up (4-wheel drive)= US$44118. This item is very necessary to monitor the project work in the remote areas where public transportation system does not exist.

The other costs are fuel and oil and repair etc. Fuel and oil cost: US$2942/year.

Leaflet/poster for the farmers (for advertising to attract more farmers): US$2942 (only one time)
Cultivation manual (planting method and other cultivation activities): US$2205 (only one time)
Overhead cost (7 % of the total cost): Overhead cost involves rent of the office, electricity, gas, office maintenance(computer and accessories) etc.
Contingencies: (3 percent of the total cost)

Plan of work:

Land will be selected in different places to facilitate more land in the jatropha cultivation in Bangladesh. Initially model farm will be established in Keshoreganj, Baluka and simultaneously business plant work will start in the Chittagong hill tracts area, specially in Bandarban area.
Mother seed will be imported from India. The seed quality will be such that it should be high in yielding capacity and dwarf in nature. Now is the appropriate time to produce seedlings. Propagation can be made either from direct seedling or from cuttings. First harvesting from direct seeding requires at lease two years and that of cuttings are 4 to 5 moths. Initially we have no scope for cuttings. This can be possible from two years old plants grown from direct seedlings.

All field supervisors, Jatropha cultivators and Stockholders will be trained on the seed quality testing, soil preparation and pit making, fertilizer application methods, pruning, other intercultural operations, harvesting technique etc.

In each location, one field supervisor will be appointed to look after jatropha cultivation processes. Team leader of the group will periodically visit to all sites to observe the cultivation processes.

Seed will be collected from farmers by the field supervisor and finally these will be sent to the central processing centre.
Monthly meeting will be held under the chairmanship of the team leader of the business group.

One workshop will be arranged in each year to discus the jatropha cultivation, oil production and advantages and disadvantages of the program.

1. Year wise cost involvement for the cultivation of 100 ha land in US$ (calculation procedures as mentioned above is followed)

	Year 1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Total for 10 year
Land (lease) for 10 yrs.	454044	-	-	-	-	-	-	-	-	-	454044
Seedlings	15600	-	-	-	-	-	-	-	-	-	15600
Reclamation & cultivation cost	11050	-	-	-	-	-	-	-	-	-	11050
Fertilizer & Irrigation	9000	2970	3118	3118	3273	3273	3273	3436	3436	3607	38504
Sand & compost	2360	-	-	-	-	-	-	-	-	-	2360
Intercultural operations (pruning & care)	6630	6630	6630	6630	6630	6630	6630	6630	6630	6630	66300
Harvesting & drying fruits	-	-	3315	3315	3315	3315	3315	3315	3315	3315	26520
Seed separation & seed drying	-	-	2210	2210	2210	2210	2210	2210	2210	2210	17680
Packaging materials (sack)	-	-	1000	1000	1000	1000	1000	1000	1000	1000	8000
Trucking cost	-	-	4000	4000	4000	4000	4000	4000	4000	4000	32000
Honorarium for company chairman	2206	2206	2206	2206	2206	2206	2206	2206	2206	2206	22060
Team Leader	15882	15882	15882	15882	15882	15882	15882	15882	15882	15882	158820
Managing Director	14500	14500	14500	14500	14500	14500	14500	14500	14500	14500	145000
Manager	3529	3529	3529	3529	3529	3529	3529	3529	3529	3529	35290
Field supervisor, 4 no.	10608	10608	10608	10608	10608	10608	10608	10608	10608	10608	106080
Driver, 1	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	12000
Office attendant, 1 No.	600	600	600	600	600	600	600	600	600	600	6000
Nursery labour, 2 no.	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	12000
Nursery construction	12500	-	-	-	-	-	-	-	-	-	12500
Cost of 4-WD Jeep, 1 No.	44118	-	-	-	-	-	-	-	-	-	44118
Repair and maintenance of Jeep	-	590	590	590	590	590	590	590	590	590	5310
Fuel and oil	2942	2942	2942	2942	2942	2942	2942	2942	2942	2942	29420
Visit &Per diem	6960	6960	6960	6960	6960	6960	6960	6960	6960	6960	69600
Leaflet/poster	2942	-	-	-	-	-	-	-	-	-	2942
Cultivation manual in Bengali	2205	-	-	-	-	-	-	-	-	-	2205
Seed, 1000 kg	2000	-	-	-	-	-	-	-	-	-	2000
Local office	8000	-	-	-	-	-	-	-	-	-	8000
Misc.	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	40000
Sub-total	634076	73817	84490	84490	84490	84490	84490	84490	84490	84490	1385403
Contingencies, 3% of the sub-total total	19022	2214	2535	2535	2535	2535	2535	2535	2535	2535	41562
Overhead cost, 7% of the sub-total total	44385	5167	5914	5914	5914	5914	5914	5914	5914	5914	96978
Grand total	697483	81198	92939	92939	92939	92939	92939	92939	92939	92939	1523943
Estimated Seed production, ton	-	-	200	450	700	800	900	1100	1300	1400	6850
Estimated oil production (35%), ton			70	157.5	245	280	315	385	455	490	2397.5
Estimated price, US$											2397500

For easiness of calculation and avoid misunderstanding, present price rate is used for overall calculations.

2. Business plantation for 2000 ha

Model farm should be established in the farmer's field. This will grow interest among the farmers and they will put more land for Jatropha cultivation in the country. Business plantation can be done in the hilly areas, public lands.
For business plantation, same facility as mentioned in the model farm should be followed.

	Year 1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Total for 10 year
ease) for 10 yrs.	9080880	-	-	-	-	-	-	-	-	-	9080880
ıgs	312000	-	-	-	-	-	-	-	-	-	312000
ıation & cultivation	221000	-	-	-	-	-	-	-	-	-	221000
er & Irrigation	180000	59400	62360	62360	65460	65460	65460	68720	68720	72140	770080
compost	47200	-	-	-	-	-	-	-	-	-	47200
ltural operations ıg & care)	132600	132600	132600	132600	132600	132600	132600	132600	132600	132600	1326000
ting & drying fruits	-	-	66300	66300	66300	66300	66300	66300	66300	66300	530400
separation & seed	-	-	44200	44200	44200	44200	44200	44200	44200	44200	353600
ȷing materials(sack)	-	-	20000	20000	20000	20000	20000	20000	20000	20000	160000
ıg cost	-	-	80000	80000	80000	80000	80000	80000	80000	80000	640000
ırium for company an	44120	44120	44120	44120	44120	44120	44120	44120	44120	44120	441200
.eader	15882	15882	15882	15882	15882	15882	15882	15882	15882	15882	158820
ing Director	14500	14500	14500	14500	14500	14500	14500	14500	14500	14500	145000
er	3529	3529	3529	3529	3529	3529	3529	3529	3529	3529	35290
upervisor, 6 no.	15912	15912	15912	15912	15912	15912	15912	15912	15912	15912	159120
1	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	12000
attendant, 1 No.	600	600	600	600	600	600	600	600	600	600	6000
y labour, 2 no.	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	12000
y construction	12500	-	-	-	-	-	-	-	-	-	12500
f 4-WD Jeep, 1 No.	44118	-	-	-	-	-	-	-	-	-	44118
and maintenance of	-	590	590	590	590	590	590	590	590	590	5310
ıd oil	2942	2942	2942	2942	2942	2942	2942	2942	2942	2942	29420
Per diem	6960	6960	6960	6960	6960	6960	6960	6960	6960	6960	69600
/poster	2942	-	-	-	-	-	-	-	-	-	2942
tion manual in i	2205	-	-	-	-	-	-	-	-	-	2205
office	8000	-	-	-	-	-	-	-	-	-	8000
	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	40000
tal	10154290	303435	516895	516895	516895	516895	516895	516895	516895	526675	14602665
gencies, 3% of the al total	304629	9103	15507	15507	15507	15507	15507	15507	15507	15800	438080
ad cost, 7% of the al total	710800	21240	36183	36183	36183	36183	36183	36183	36183	36867	1022187
total	11169719	333778	568585	568585	568585	568585	568585	568585	568585	579342	16062932
ted Seed production,	-	-	4000	9000	14000	16000	18000	22000	26000	28000	137000
ted oil production ton			1400	3150	4900	5600	6300	7700	9100	9800	47950
ted price, US$			1400000	3150000	4900000	5600000	6300000	7700000	91090000	9800000	47950000

Break-Even Analysis and Forecasting:

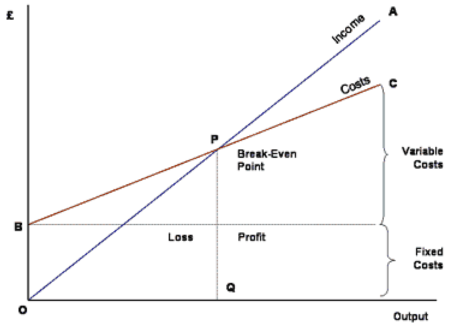
Break-even analysis depends on the following variables:

1. Selling Price per Unit: The amount of money charged to the customer for each unit of a product or service.
2. Total Fixed Costs: The sum of all costs required to produce the first unit of a product. This amount does not vary as production increases or decreases, until new capital expenditures are needed.
3. Variable Unit Cost: Costs that vary directly with the production of one additional unit.
4.Total Variable Cost The product of expected unit sales and variable unit cost, i.e., expected unit sales times the variable unit cost.
5. Forecasted Net Profit: Total revenue minus total cost. Enter Zero (0) if you wish to find out the number of units that must be sold in order to produce a profit of zero (but will recover all associated costs)
Each of these variables is interdependent on the break-even point analysis. If any of the variables changes, the results may change.
Total Cost: The sum of the fixed cost and total variable cost for any given level of production, i.e., fixed cost plus total variable cost.
Total Revenue: The product of forecasted unit sales and unit price, i.e., forecasted unit sales times unit price.
Break-Even Point: Number of units that must be sold in order to produce a profit of zero (but will recover all associated costs). In other words, the break-even point is the point at which your product stops costing you money to produce and sell, and starts to generate a profit for your company.
One may use the JavaScript to solve some other associated managerial decision problems, such as:

- **setting price level and its sensitivity**
- **targeting the "best" values for the variable and fixed cost combinations**
- **determining the financial attractiveness of different strategic options for your company**

The graphic method of analysis (below) helps you in understanding the concept of the break-even point. However, the break-even point is found faster and more accurately with the following formula:

$Q = F_C / (U_P - V_C)$
where:
Q = Break-even Point, i.e., Units of production (Q),
F_C = Fixed Costs,
V_C = Variable Costs per Unit
U_P = Unit Price
Therefore,
Break-Even Point Q = Fixed Cost / (Unit Price - Variable Unit Cost)
One may like using the JavaScript for performing some sensitivity analysis on the above parameters to investigate their impacts on your decision-making.



Selling Price per Unit ($) :	
Total Fixed Costs ($) :	
Variable Cost per Unit ($) :	
Forecasted Net Profit :	
Managerial Information at the Break-Even Point	Numerical Results
Units Sold :	
Revenue ($) :	
Fixed Costs ($) :	
Variable Costs ($) :	
Total Costs ($) :	
Loss/Profit ($) :	

An Alternative Break-Even Calculator	
Interest Rate or Taxes (%) :	
Total Fixed Costs ($) :	
Variable Cost per Unit ($) :	
Selling Price per Unit ($) :	
Break-Even Point :	

Experience from different countries:
1. The Jatropha plant in Zambia
Jatropha curcas is not an indigenous plant to Zambia, but it is known all over the country in small quantities. Only in Eastern, Western and North-Western Province are areas where it is abundant. Since the plant is not browsed by animals, Jatropha is used by the farmers to protect their gardens against roaming animals. In the other parts of the country the Jatropha plant is used only as an ornamental plant, and is not exploited commercially.
It seems that the plant was introduced to Zambia from Angola and Mozambique, where the plant is widespread. In Southern Province it seems that returning workers from Zimbabwe took seeds with them and planted them around their houses.

2. Short description of "The Jatropha System"
The Jatropha System is an integrated rural development approach. By planting Jatropha hedges to protect gardens and fields against roaming animals, the oil from the seeds can be used for soap production and as fuel in special diesel engines. In this way the Jatropha System covers 4 main aspects of rural development:
promotion of women (local soap production);
poverty reduction (protecting crops and selling seeds).
erosion control (planting hedges);
energy supply for lighting and stationary engines in the rural area;

The obvious advantage of this system is that all processing, and thus all value added, can be kept within the rural area or even within one village. No centralized processing (like in the cotton industry) is necessary.

Origin of Jatropha
Jatropha curcas originates from Central America and was distributed by Portuguese seafarers via the Cape Verde Islands to countries in Africa and Asia.

The plant: Jatropha curcas L.
The Jatropha plant is a small tree or large shrub which can reach a height of up to 5 m. The lifespan is more than 50 years. The plant is a drought resistant species which is idly cultivated in the tropics as a living fence, because it is not browsed by animals. The seeds are toxic to humans and many animals. Because of its properties in most

countries Jatropha is planted in the form of protection hedges.

Yield
Figures given in the pertinent literature vary from 300 g to 9 kg per tree and year. On a hectare basis, this is between 2 and 5 tons per hectare

Generative propagation (seeds)
The best time for direct seeding is the beginning of the rainy season. The seeds are sown in the soil at a depth of 2-3 cm. After 2 years, or 3 rainy seasons, the Jatropha plants produce new seeds.

Vegetative propagation (cuttings)
Jatropha is very easy propagated from cuttings, which are placed about 20 cm into the soil. The cuttings should be older than 1 year, already lignified and about 60 to 120 cm long.

The best planting time is 1 to 2 months before the beginning of the rainy season, in Zambia in September/October. For live fencing the cuttings can be planted like a fence of dead wood, one cutting beside the other. The cuttings should be 20 cm in the soil, on the top they are fixed with horizontal branches. The protection function is thus achieved immediately and within a few weeks the cuttings start to grow. If well maintained, this kind of live fence can even keep chicken out of gardens. Cuttings can easily be kept in a shaded place for a few weeks, without drying. A cover of wax on the leaves and on the bark reduces the evaporation. The cuttings will start to rot before they dry out.

Its possible uses
The plant is widely used as a source of local medicine.
Besides of this in almost all countries it is used for boundary demarcation and for live fencing.
Together with stone walls, small earth dams or Vetiver grass it is very useful to fight erosion.
The seeds can be processed (oil, press cake) or sold directly as seed or for industrial use.
The Castor Company of Zambia (CCZ) also seems to be interested in buying Jatropha seeds for industrial purposes.
The seeds contain 32 to 35 % of oil. With mechanic oil expellers (like the Sundhara press) up to 75 - 80 % of the oil can be extracted. With the Yenga hand press about 60 - 65 % of the oil can be extracted (5 kg of seeds give about 1 liter of oil).
Because of its mineral content, which is similar to that of chicken manure, it is valuable as organic manure. In practical terms an application of 1 t of JCL press cake is equivalent to 200 kg of mineral fertilizer.
Due to its residual oil content, the JCL press cake also has insecticide properties, and reduces the amount of nematodes in the soil.
The most interesting and economically viable use of the Jatropha oil is soap production. Jatropha oil gives a very good foaming, white soap with positive effects on the skin, partly due to the glycerine content of the soap.
To use Jatropha oil for lighting the paraffin lamps have to be converted, as Africare did or a floating wick can be used, as it was invented by the Binga Trees Trust. A cooking stove for Jatropha oil has not yet been developed.

Exploitation of the Jatropha plant

Oil extraction

Preparing / roasting 6 kg of seeds

To prepare the seeds for oil extraction, they should be heated, either in full sunlight on a black plastic sheet for several hours or in a roasting pan for 10 minutes. Careful: the seeds should be heated, but not burnt. This process breaks down the cells that contain the oil, allowing the oil to
flow out more easily. The heat also liquefies the oil, which improves the extraction process.

The hopper guides the seeds to the piston. Because of its small diameter, the flow of seeds is often blocked. With a thin stick the seeds should be pushed into the tube and the piston. Usually there is a thin iron bar fixed at the lever of the press, which does this automatically.

The piston creates the pressure to force the oil out of the press cake. Sometimes the piston gets stuck and is difficult to move. Then the press has to be taken apart and the piston and its cylinder have to be cleaned thoroughly.

The cage is welded from iron bars with a fine gap between them. Before starting the pressing make sure that the gaps are free.

The outlet is the regulation part of the ram press. The more it is closed, the more difficult it is to press the cake through the gap, the more oil is extracted (higher extraction rate). The outlet should be regulated in such a way that one person can push down the lever without too much force (not "hanging" on the lever).

There are three ways to purify the oil:

1. Sedimentation
This is the easiest way to get clear oil, but it takes up to one week until the sediment is reduced to 20 - 25 % of the volume of the raw oil.

2. Boiling with water
The purification process can be accelerated tremendously by boiling the oil with about 20% of water. The boiling should continue until the water has evaporated (no bubbles of water vapor anymore). After a short time (a few hours) the oil then becomes clear.

3. Filtering
Passing the raw oil through a filter is a very slow process and has no advantage in respect of sedimentation. It is not recommended.

Participants try their hand
An important aspect of the demonstration of oil extracting is that participants get a chance to try operating the press. Each participant has to move the lever about 10 times to get a feeling of the force necessary. More than 1 litre of raw oil must be produced to replace the oil which is used for the soap making demonstration.

Cleaning of the press
After extracting Jatropha oil with the Yenga press, the press must be cleaned very thoroughly before it is used to extract oil for cooking. At least one kg of edible seeds must be extracted (and the oil thrown away) before the press can be used normally for edible oils.

Demonstration of soap making
For soap making, purified Jatropha oil has to be used. Since the purification takes some time to produce clear oil, the necessary amount of purified oil should be prepared and taken to the demonstration site. The oil produced during the demonstration of the Yenga press can replace some of this oil.

The components of soap making
The soap formation is a chemical reaction between the oil and the caustic soda. The main components are:

Plant oil Water Additives like Caustic soda
perfumes,
honey, flower,
starch

Making the caustic soda solution
The components for soap making are:
1 litre of oil,
0.75 litre of water
150 g of caustic soda per litre of oil
If no scale is available, the components can be measured by volume, for instance: cups:
8 cups oil
6 cups water
1 cup caustic soda

To prepare the solution of caustic soda, To prepare the solution of caustic soda, calculate the amount of caustic soda and put the soda into the water.

Never pour water onto caustic soda!

Stir the solution until the caustic soda is dissolved. The solution will get hot. To continue the work, wait until the solution cools down (you can accelerate this by standing the bowl with the solution inside a larger bowl filled with cold water while you stir).

Mixing oil with solution

Pour the oil into a bowl and put it beside the bowl of caustic soda solution. Pour the caustic soda solution slowly into the oil stirring all the time. There will be a reaction immediately: the mixture will go white and very soon (after a few minutes) it becomes creamy. Continue stirring until the mixture is like mayonnaise. Then you can add perfumes or other additives to improve the soap or to give it an individual touch.

Pouring into moulds
If the consistency is still creamy, you should pour the mixture into a mould, where it can harden overnight. The moulds can be made from a wooden tray or a cardboard box, lined with a plastic sheet. To make some other forms, you can also use yoghurt cartons or any other plastic container as a mould. Some of these plastic containers (water bottles) have interesting designs at the bottom, which give nice soap forms, if only the bottom part is used as a mould.

Variations of soap components (perfumes)
An important factor to change the properties of the soap is the water content. It can differ by 100 %. The above mentioned quantities give a medium-hard soap. If the quantity of water is only half the quantity of oil, the soap becomes very hard. If the water quantity is equal to the quantity of oil, several spoonfuls of flour and starch will have to be added to obtain a soap which is hard enough. Without the flour the soap stays too soft. Economically it is a big advantage to add flour and more water, because more pieces of soap can be produced with the same amount of oil and caustic soda.

Cutting the soap
The time needed for the hardening process depends on the ambient temperature. At about 30 ℃ the soap hardens overnight and can be cut into pieces the next morning. At lower temperatures this process can take some days. If the soap has become too hard it has to be cut with a saw. For marketing purposes the pieces of soap should not be too big. 100 to 150 g seems to be a size which fits nicely into the hand. A piece of soap 8 cm long, 5.5 cm wide and 2 cm thick weighs about 100g. It is big enough to put a label on.

Storage
The soap making process is a chemical reaction which is very fast at the beginning and continues for some time more slowly. Therefore, the soap should be left for at least 2 to 3 weeks on a shelf (to ripen) before being used. Since the soap contains a surplus of water, it will lose some weight during storage in the dry season.

Packaging
If the soap is to be sold outside the village, it should be wrapped in some nice paper, or in transparent plastic with a label.
Cleaning the material
Since the oil is toxic and the caustic soda a very aggressive chemical product, all material should be cleaned thoroughly after the demonstration using a lot of water.

Lighting with Jatropha oil
Lighting is a basic need and paraffin is not always available in rural areas. So people use diesel instead. It smokes badly and many people cannot stand the smell. Health hazards too have been reported. Taking into consideration the differences between Jatropha oil and paraffin, two lamp designs for Jatropha oil have been developed:

Using the paraffin lamp for Jatropha oil
The body of a normal petrol lamp is modified: the mechanism to move the wick is fixed inverse to the reservoir to reduce the height between surface of the oil and flame. This design is promoted by Africare in Lusaka.

The Binga lamp for Jatropha oil
A simple and very appropriate design of an oil lamp has been developed by the "Binga Trees Trust" on the Zimbabwean bank of Lake Kariba. This design works very well and can be assembled in each village. See detailed description below: The "Binga-Oil-Lamp" is made of a simple glass (jam jar, drinking glass), filled with oil up to 3 - 5 cm below the rim. On the oil floats a small cork disc (or a disc of a maize spindle) wrapped in aluminium foil to prevent the cork burning. In a hole in the centre of the disc a cotton wick is fixed. The floating wick holder is centred using match sticks or pins. Thus the flame of the oil lamp is only some 1 or 2 mm above the surface of the oil and the flame gives a quiet and steady light. It seems that the smell of this light also repels mosquitoes.

Plantation of Jatropha

Planting hedges from seeds
Seeds are planted at the beginning of the rainy season. To get a dense hedge to protect gardens against browsing animals, a seed should be planted every 5 cm. The germination should be controlled and missing plants replaced by new seeds. To achieve a dense hedge it is also possible to plant the seeds alternately in two rows, 20 cm apart. The seeds themselves should be 10 to 15 cm apart. Since the young Jatropha plants have not yet developed their repellent smell, they might be eaten by roaming animals, so they should be protected during the first year with some tree branches. After three rainy seasons the plants are big and dense enough to protect the crops.

Planting hedges from cuttings

It is better to plant a hedge from cuttings, if they are available. The best time to plant cuttings is during the dry season, 1 to 2 months before the beginning of the rainy season. The cuttings should be already lignified, i. e. more than 1 year old. Old branches of some years of age can also be used as cuttings. The cuttings can be placed 3 to 5 cm into the soil and fixed 1 m above the soil with a horizontal wooden bar. The protective function is thus achieved right from the outset and the fence will start living during the rainy season.
Old and strong branches can also be used as poles for fencing with barbed wire, because the poles start growing and are less likely to be attacked by termites.

Establishment of a plantation
To start a Jatropha plantation the above mentioned planting methods can be used. The plants should be 2.5 m apart with a distance of 3 m between the rows. If the plants are too close together you will find it difficult to harvest the seeds.

Useful addresses in Zambia

Promotion
Africare
P.O. Box 33921, Lusaka
Tel: 29 36 34, Fax: 29 36 31, e-mail: africare@zamnet.zm

Castor Growers Association of Zambia (CGAZ)
Attn. Mr. Mutebela, Chairman
Off Makishi Road, 26 Mwalule Crescent
P.O. Box 38376, Lusaka
Tel: 23 76 18, Fax: 23 76 18 or 29 09 37

Production of oil presses / expellers:
Jung, Producer of the Sundhara press in the Copperbelt
Yenga & Sunflower Association of Zambia

Caustic soda
Farmers Barn Ltd,
P.O. Box 37254, Chiparemba Road, Lusaka
Tel: 223671, Fax: 225352, Cell: 703151,
- Branch Lusaka: Opp. New City Market Soweto Area, Tel: 286607
- Branch Choma: Tel: 032 20344
- Branch Kabwe: 05 221478
- Branch Ndola: Chisokone Avenue, P.O. Box 71270, Tel: 620439

Yaweh's Pharmacy Ltd,
P.O. Box 670479, besides Commercial Bank,
Mazabuka, Tel: 03 30847
Oil extraction:
M. A. Deliverance Agro-Industries, Oil expellers,
P.O. Box 670285, Mazabuka, Tel: 300530, Mr. Sharma

Buying seeds:

Castor Company of Zambia Ltd (CCZ)
Attn. Mr. Mukutu, Chairman
Off Makishi Road, 26 Mwalule Crescent, P.O. Box 38376, Lusaka,
Tel: 01 23 76 18, Fax: 23 76 18 or 29 09 37

Castor Growers Association of Zambia (CGAZ)
Attn. Mr. Kaula Mutebela, Chairman
Off Makishi Road, 26 Mwalule Crescent, P.O. Box 38376, Lusaka,
Tel: 01 23 76 18, Fax: 23 76 18 or 29 09 3
KGN Exports
Attn. Mr. Suresh Babu
M 58, VOC Nagar, Behind Police Quarters, Ganapathy
Coimbatore - 641 006, Tamil Nadu, India
Phone: +(91)-9894045389/9443332441
Email: ksbagri@yahoo.com

Westec Bioenergy Corp.
Attn. Mr. Wesley Chen
120 / 529, Soi Naksuwan, Nonsi Road, Yannawa, Bangkok, Bkk, Thailand - 10120
Telephone: +66-87-9393058
Fax: +66-2-6817842

FUTURE of BIODIESEL PRODUCTION in INDIA based on JATROPHA OIL
There is no scope in near future, for BioDiesel Plant without back to back Jatropha Plantation. Currently 3 plants are producing BioDiesel in Maharashtra, India. These three are 20 years old plants, producing fine chemicals in the past. These plants are using imported Used Oil or non-edible Palm Oil Fractions, as raw material. The present capacity of these units together is 150,000 liters per day, but these can produce 500,000 liters per day, if raw material is available. There are many other old plants, which can be easily converted to BioDiesel Plant with minor modifications. The number of new grass root plants are struggling for completion.

BioDiesel manufacturers in India, are currently facing a big hurdle: Collection, Procurement, Transport and Storage of Jatropha / Pongamia (Karanj) / Castor Seeds. Most of the plantations are currently going on in the small farms of 1 to 10 acres. The quantity of seeds produced from such farms will be few tons, available in pockets, spread all over the states.
Collecting these and storing at a central place where a BioDiesel plant can be set up, is a logistical nightmare. Farmers may get higher price for their seeds, for consumption of oil as fuel for heating and lighting and may use it locally. He can use cake as Organic Fertilizer. Also the availability of seeds is once a year (if land is rain

fed) or once in six months (if land is irrigated). Initially Jatropha oil will be available, only during harvesting, for one or two months, once or twice a year. Jatropha oil hydrolyses on storage and then simple trans-esterification process can not be used for BioDiesel manufacture. To run BioDiesel plant throughout the year, seeds will have to be stored for rest of the 8 months. This will require huge inventory and will lead to huge finance costs.

Initially, most of the oil will be used as it is for heating in stoves, and for lighting in lanterns since it will be easier for farmer to process the seeds locally, and he can get better value for his produce locally. It will also be used in Diesel Engine based Electricity Generating sets, Pump Sets, Heavy Farm Machinery, which can run on high viscosity oil. The requirement for this sector is 20 to 25 million tons per year. Looking at current rate of production of Jatropha Oil, this sector will use most of the oil produced for next five years and no oil will be available from small farmers, for Manufacture of BioDiesel.

BioDiesel can be manufactured in small plant of 1,000 liters per day to large plants of 100,000 liters per day or more.

1,000 liters per day: The plant will need 3 to 4 tons of seeds every day. It should get a truckload of seeds every three days, in harvesting season. For other period, a storage of at least 4 months will be required. 4,800 tons of seeds will have to be stored for plant of this size. This will require a closed godown of 4,000 square meters and finance of Rupees 48 million (US$ 1 million). Arrangements should be made for handling, storage and disposal of oil cake. This will require a closed godown of 1,000 square meters. Plant of this size will have no problems in procuring other raw materials, such as Methanol and Caustic Potash, but if bought in smaller volumes, these will be expensive.

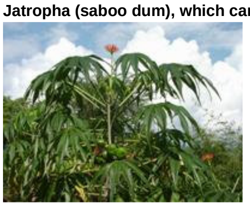
1. 100,000 liters per day : The plant will need 300 to 400 tons of seeds every day. It should get 30 to 40 truckloads of seeds every day, in harvesting season. For other period, a storage of at least 4 months will be required. 480,000 tons of seeds will have to be stored for plant of this size. This will require a closed godown of 400,000 square meters and finance of Rupees 4.8 billion (US$ 100 million). Arrangements should be done for handling, storage and disposal of oil cake. This will require a closed godown of 1,00,000 square meters.

Plant of this size will have some problems in procuring other raw materials, such as Methanol and Caustic Potash. 5 to 6 truckloads of methanol and 1 truckload of Caustic Potash will have to be procured and handled per day.

In this scenario both large and small plants will have problems for at least next few years. Procurement of seeds locally, is going to be biggest challenge. To overcome that, Jatropha Plantations should be set up on large plots of land. For a BioDiesel Plant of 1,000 liters per day, 500 acres or 200 Hectares (2 square kilometers) of Plantation is required. For bigger plants, larger plantations are required. These can be as patches of plantations of 500 acres in one place, scattered all over a state. This will lead to a lot of investment in plantations. A lot of employment will be generated through plantation activities. Rural people will get employment locally, and need not go to large cities to work and earn a living.

Thailand:

The rising prices of traditional fuel and a government policy to promote alternative energy provide an opportunity for British D1 Oils Plc to produce biodiesel from Jatropha (saboo dum), which can grow in northeastern Thailand.



D1 has developed a portable refinery technology to produce biodiesel for the UK transport industry. It has called on the Thai government for help in promoting Jatropha, a raw material for biofuel refining. The company hopes the government will float diesel prices, which would make its proposed biodiesel project viable, according to D1 managing director Mark Quinn. Jatropha is a highly diverse plant, which always contains a milky sap irritating to humans, and often has flowers. Varieties can look like a cactus, an extremely leafy plant or a tree.

Mr Quinn said the company, in collaboration with Chamnan Chutkaew, a lecturer at Kasetsart University, had genetically modified the plant to produce a higher quality of

the Jatropha oil, increase yields and make the variety more durable against drought. Research and development took place at plantations established in 24 provinces, all in the Northeast. Jatropha, which grows in several areas of Thailand, is highly resistant to drought, and thrives in arid areas. The plant produces oil-bearing seeds within six months of planting. The price of Jatropha seeds is unlikely to vary, because the plant is inedible, while demand for biodiesel is increasing continuously. Mr Quinn said it took a long time to find suitable families of Jatropha for growing in the Northeast. The likely biodiesel formula would be 10% Jatropha and 90% regular diesel. The product would be commercially viable if diesel fuel were sold locally at the true market price, instead of being subsidised by around three baht a litre, the company says. D1 says it can refine up to five million litres of Jatropha oil per year from plantations totalling 31,205 rai. It takes four kilogrammes of Jatropha seeds to refine into one litre of oil. It was hard to find that much land for Jatropha growth, because farmers considered it only a secondary crop. Therefore, said Mr Quinn, it would be mutually advantageous for the governmnet and D1 to join hands to encourage farmers to grow Jatropha. In the tests in the Northeast, the average total revenue per hectare for farmers was around 67,000 baht from growing 416 kg a year _ 12,727 kg, or two million baht in 30 years. Estimated biodiesel production per hectare was about 3,000 litres over the same 30 years. Under the project, D1 would offer a purchase guarantee of Jatropha seeds, and guarantee domestic markets for biodiesel distribution. This could convince farmers in the Northeast to make Jatropha a priority crop, said Mr Quinn. D1 hopes to have 188,000 hectares of plantations under Jatropha in Britain, India, the Philippines and South Africa by 2008, for refining 220 million litres of biodiesel per year. Current global biodiesel production is 1.3 million tonnes of crops, expanding by 14% a year and likely to reach 2.7 million tonnes by 2010. Phichai Tinsuntisook, president of Royal Equipment Co, which is developing the Jatropha plantation for refining, said Thailand had nothing to lose in promoting Jatropha for biodiesel production. Because Jatropha is inedible, prices will not swing like other oil-bearing crops such as palm or coconut. According to Mr Phichai, government may help after some private sectors commercialise Jatropha products. For example, a construction company is growing Jatropha, and believes it can reduce fuel expenses from one billion baht per year to 700 million baht. Other companies are growing Jatropha to export to China. Like all biodiesel, Jatropha cannot be traded as a replacement for petroleum. To encourage farmers to grow Jatropha commercially, the government should classify biodiesel from Jatropha the same as diesel, and allow legal sale in the market, Mr Phichai said.

Pakistan :

Business Mission: 5 year goal

1. **Produce 0.5% of our current diesel consumption i.e. plant 16,000 hectares ourselves**
2. **Develop research and development facilities at leading national universities in oilseed genetic studies, oscillatory flow mixing/continous flow esterfication units and thermal depolymerization processes**
3. **Help develop nurseries and plantation for 10% of our current diesel consumption, i.e. 800 million saplings, 8,000 sq km**
4. **Insha'allah one day to be self sufficient in diesel, and perhaps even export it. For this to happen in the conceivable future, a major rethinking is required by our policy makers and perhaps only if oilgae becomes a viable option, as 10% of pakistan to jatropha cultivation would truly be a divine miracle.**
5. **Objectives of our Mission : Make Jatropha cultivation and biodiesel production a low-risk venture with attractive returns.**
6. **Help attract private investors in Jatropha cultivation and biodiesel production development.**
7. **Promote and recognize endeavors to build technical capacities of rural entrepreneurs.**
8. **Help create new work opportunities in Jatropha cultivation and biodiesel production related sectors.**
9. **Highlight environmental and social integration of Jatropha cultivation and biodiesel production systems in rural communities.**
10. **Provide gender sensitive socio-economic and environmental analysis of Jatropha cultivation and biodiesel production requirements in rural communities.**
11. **Work with the government to promote biodisel friend policies, aid, grants and funds for rural development.**

Jatropha curcas news:

Mr. Hak with fruits of a high yielding Jatropha plant in Sisopon, Banteay Meanchey province, Cambodia

Improvement of root initiation with plant hormones in Cambodia realized!

High yielding plant from Bali

Plant with high percentage of female flowers

Maurício Möller, Brazil

Photos of Shenyu New Energy Ltd., Yunnan, China,



Jatropha grafting in Domenican Republic !

High Yield Jatropha Plants in Brazil

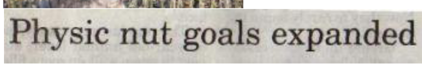

good yielding bush


50 year old Jatropha tree

In Indonesia they succeeded to select some early flowering and high yielding Jatropha plants and multiplied them by cuttings in an industrial scale in nurseries. Here are some of the photos:

 Photo: group Ardiya	 Photo: group Ardiya	 Photo: group Ardiya	

Jatropha in Myanmar


Physic nut goals expanded


Weeding in seedling base


Working in seedling base


High yield plant in demonstration plantation

Photos: Jatropha activities by the Shenyu New Energy Company in Yunnan, China

Madarail, a private

enterprise which runs the railway system of Madagaskar, is planning to run the train from Antananarivo to Toamasina (Tana - Côte est, TCE) with Jatropha oil. Each year about 100 ha of Jatropha plantation shall be created. See the photo of a similar train at right.

FCE-train

The Bielenberg Ram Press now produced in Madagascar

Valy Jatropha press at ERI in Fianarantsoa, Madagascar

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Appendix-1: CURRICULUM VITAE OF PROF. DR. ENGR. MD. DAULAT HUSSAIN

Name : PROF. DR.. MD. DAULAT HUSSAIN
Father's Name : Late Mvi. Ahmed Hussain

Present address: Department of Farm Power and Machinery
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Tel.: + 880 91 55045 (res.)
Mob.:+88-01716-411105
E-.mail: dhussainbau@yahoo.com

Date of birth: 31 December 1950

Education:

- **Dr.Sc.agr. from the Institute of Agricultural Engineering, University of Hohenheim, Stuttgart, Federal Republic of Germany, 1984, GRADE: CUMLAUDE**
  Field of study and research: Spray technology
- **Master of Engineering (M.Engg.) from the Asian Institute of Technology, Bangkok, Thailand, 1977**

Field of study and research: Agricultural System Engineering and solar energy, Grade: Very Good

- **Bachelor of Science in Agricultural Engineering (B.Sc.Ag.Engg) from Bangladesh Agricultural University, Mymensingh-2202, Bangladesh, 1972, Stood First in the First Class**

Field of study and research: Agricultural Engineering (Agricultural Mechanization)

- **Basic Science and language, Bangladesh Agricultural University, Mymensingh, 1967, Stood Second in first division**
- **Secondary School certificate examination: Stood second in First division (Ag. Group), Dhaka Board, 1965**

SUMMARY of Educational qualification:

Certificate/Degree/Postdoc training	Year	School/College/University	Division/Class	Position/Grade
S.S.C.	1965	Mohanganj Pilot High School	Ist division	Stood second in Ag. Group
Basic Science & Language	1967	BAU, Mymensingh	Ist division	Stood second
B.Sc.Ag.Engg	1971	BAU, Mymensingh	Ist Class	Stood first
M.Engg.	1977	AIT, Bangkok	GPA 3.21	Very good
Dr.Sc.agr.	1984	Universitat Hohenheim, Germany	Cumlaude	-
Post doc.	1989-90	SRI,UK under Commonwealth Academic Staff Fellowship	completed	-
Post doc.	1990	Uni.Hohenheim,,DAAD fellowship, Germany	completed	-
Post doc.	1996	Uni.Hohenheim,DAAD Fellowship, Germany	completed	-
Post doc.	2000	Uni.Hohenheim,DAAD fellowship, Germany	completed	-
Post doc.	2002	Uni.Hohenheim,DAAD fellowship, Germany	completed	-
Post doc.	2003	Mie University, JSPS, Japan	completed	-
Post doc.	2005	Uni.Hohenheim,DAAD fellowship, Germany	completed	-

Job objective:

Teaching: Plant protection techniques, Farm Power, Heat engines and thermodynamics, Agricultural Machinery, Machine design, Heat and Mass transfer, Workshop technology, Theory of Machine

Research: Agricultural Mechanization, Spray technology, Solar and renewable Energy, Biomass, Rainwater harvesting, harvesting of fruits, wastewater management and short rotation plantations(SRPs) plantation, biodiesel and bio-ethanol production.

Experience: Teaching, research and other assignments in Farm Power and Machinery, Solar Energy, pesticide application technique; worked as principal Investigators in different research projects funded by national and international organizations. Preparation of projects proposals, such as TAPP, Concept notes and project proposals for developmental works. Supervised the research work of MS and Ph.D. students of the department of Farm Power & Machinery, BAU, Mymensingh.

Research projects completed:

* **Arsenic removal from shallow tube well water- Funded by BAU, Mymensingh**
- **Rain water harvesting in Dacope- funded by IDRC, Canada**
- **Performance studies of country ploughs- funded by BAU, Mymensingh**

- **Country plough project- funded by DANIDA-IRDP**
- **Power tiller mounted sprayer- funded by BAU, Mymensingh**
- **Power tiller mounted sugarcane harvester- funded by BAU, Mymensingh**
- **Harvesting Juice from Date and Palmyra palm tree- funded by BAU, Mymensingh**
- **Bamboo made jute seed drill-funded by BAU, Mymensingh**
- **Design and development of Neckharness- funded by BAU, Mymensingh**
- **Design and development of Bullockcart-funded by Planning commission of Bangladesh and ITDG, UK**
- **Research on electrostatic spraying, funded by DAAD and DFG, Germany**
- **Design and Development of multipurpose sprayer-funded by BAU, Mymensingh**
- **Storage of straw in Bangladesh**
- **Energy requirement in different tilling systems-funded by CDP of Canada**
- **Energy requirement in Rice production-funded by CDP of Canada**
- **Hand tools ergonomics- funded by DFID,UK**
- **Options for Farm Power- funded by DFID, UK**
- **Solar pond project- funded by BAU,Mymensingh**
- **Supervised students projects/Theses (BS, MS and PhD level)**
- **Integrated Approach for Sustainable Wastewater Management and Biomass production in Bangladesh(INAWAB), under the Asia Pro Eco Programme, Contract No. ASI/B7-301/2598/17-2004/79070.I worked as Team leader, WWW.INAWAB.INFO**

Position held:

- **Professor in the department of Farm Power and Machinery (8.2.92 – to date)**
- **Associate Professor in the department of Farm Power and Machinery (8.8.86- 7.2.92)**
- **Assistant Professor in the department of Farm Power and Machinery (3.9.75 – 7.8.86)**
- **Lecturer in the department of Farm Power and Machinery (22.11.72 – 2.9.75)**
- **Head of the department of Farm Power and Machinery for a period of 27 months**
- **Dean of the faculty from 2.3.2002 – 2.3.2004**
- **Head of the department of computer science and mathematics from 28.5.2002- 2.3.2004**

Others: Co-operating Editor, Journal of Agricultural Mechanization in Asia, Africa and Latin America, Japan

Editor, JAMM, Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh

Chairman, Telephone Management Committee, Bangladesh Agricultural University, Mymensingh

Member, Governing Committee, Institute of Appropriate Technology, Banglasdesh University of Engineering and Technology, Dhaka, Bangladesh

Member, Governing committee, K.B.I. College, BAU Campus, Mymensingh

Member, Academic Council of Bangladesh Agricultural University, Mymensingh, Bangladesh

Member of the BAU syndicate for a period of five months from 2.3.2002 to 2.8.2002

Scholarships & Fellowships:

- **DPI Scholarship for undergraduate study at Bangladesh Agricultural University, Mymensingh (1965-1971)**
- **CDG(INWENT) Scholarship for graduate study at Asian Institute of Technology (AIT), Bangkok, Thailand (1975-1977)**
- **DAAD Scholarship for doctoral studies at Universitat Hohenheim, Stuttgart, Germany (1980-1984)**
- **Commonwealth Academic Staff Fellowship (post doctoral) for research at Silsoe Research Institute (SRI), UK for ten months (1989-1990), Field of research: Spray technology**
- **DAAD fellowship for three months duration at Universitat Hohenheim, Stuttgart, Germany (1990), research on spray technology**
- **DAAD fellowship for three months duration at Universitat Hohenheim, Stuttgart, Germany(1996), research on spray technology**
- **British Council Scholarship for two months study at the Silsoe College, UK,1995**
- **JSPS senior fellowship for one month at Mie University, wind turbine,Japan from 28.9.03 –28.10.03**
- **DAAD fellowship for three months duration at Universitat Hohenheim, Stuttgart, Germany(2002) research on test procedures of diesel engines suitable for third world countries**
- **DAAD fellowship for three months duration at Universitat Hohenheim, Stuttgart, Germany(2005), research on spray technology at green house condition**

Foreign Language:

- **English – very good in speaking, writing and reading**
- **German language- can speak, write and read**
- **Bengali-mother tongue**

Medium of Instruction:

- **Medium of instruction both in undergraduate and graduate studies was in English**

Professional memberships:

- **Life fellow of the Institute of Engineers' Bangladesh (F 2582)**
- **Member of the BSAE, Bangladesh**
- **Member of the Bangladesh- German Universities Association in Bangladesh**
- **Member of the AIT-Bangladesh chapter in Bangladesh**

Participation in Seminar & Workshops:

- **Attended in national and international conferences, seminars and workshops in different years**
- **Visit: (1)Visit to China from 4th October 2001 to 17th October 2001 in Beijing, Nanjing, Wuxi, Changlu and Shanghai(manufacturing workshops, factories and research organizations, Institutes etc).**

(1) Visit to India from 9.2.02 to 22.02.02 in Calcutta, Delhi, Ludiana, Bhopal, Budni, Jilandhar

(manufacturing workshops on Tractors, Power Tiller, Straw combine, Potato harvester, Potato planter, Water pumps, Bee cultivation, Bio fertiler centre, CIAE, IARI etc)

(2) Visit to Thai. Universities from 22.9.2002 to 29.9.2002 to discuss the undergraduate and post graduate curricula and to develop BAU curricula.

4. Awards:

- **Awarded Chancellor's award for outstanding graduate of the year 1971**
- **Awarded Presidential award for the development of Agricultural machines, 1989**

5.Publications: Have publications in national and international journals (list enclosed)

6.Training:

- **Participated in the short course on Technology Assessment and Technology Diffusion from September 12 to September 16, 1987 at the Institute of Appropriate Technology, BUET, Dhaka**
- **Participated in the Management Training and Case writing workshop at BARC for 7 days, April, 1980**
- **Participated in training course on Testing and Evaluation of Agricultural Machinery sponsored by FAO and conducted by SRI, UK and AIT, Thailand, November 24-30, 1994 at AIT, Bangkok**
- **Attended in a short course at Silsoe College, Bedford, UK from 8.1.95 to 15.3.95 on test procedures for farm machineries including Power Tiller sponsored by ODA, UK**
- **Integration of Pollution Prevention Topics into the Engineering Curriculum, Organized under the linkage Program between BUET and NCATSU, 24th to 25th July, 2001**

* Studies on power measurement and performance evaluation of small wind energy converter, Mie university, Japan, 29.9.2003 to 28.10.2003.

7. On going projects:

1. Feasibility study on Indigo production in Modhupur Area funded by BAU, Mymensingh
2. Biodiesel production from Jatropha curcas and ethanol from the sap of Palm trees
3. Production of ethanol from cassava etc
4. Agar production in Bangladesh

Appendix-2: Following farmers are ready to put their land under the 100 ha model farm at Rangmatia, Keshoreganj.

Sl.No.	Name of farmers	Area of land, acre
1.	Jubed Ali	4.50
2	Shajahan	2.00
3	Tojammel	1.50
4	Haji Mofiz Sarkar	2.00
5	Haji Abdul Latif	2.00
6	Zafar	1.50
7	Sorab Ali	3.50
8	Abdur Razzaque	3.00
9	Shamsul Huq	1.50
10	Aziz	0.75
11	Chand	0.75
12	Shafikul	3.00
13	Abul Hossain	1.50
14	Altaf Ali	2.50
15	Ishhaque	3.00
16	Muslem	2.50
17	Tarasutar	1.50
18	Kuddus	2.00
19	Shamsu	1.00
20	Rashid	2.50
21	Jadu	2.00
22	Intaj Ali	2.00
23	Pasur Ali	1.00
24	Atab Ali	1.00
25	Enus Ali	1.00
26	Suruz Ali	3.00
27	Shamsul Haque	2.00
28	Kajjal	2.00
29	Nowsher Ali	2.00
30	Harzat Ali	4.00
31	Mufazzal Hossain	2.00
32	Mufa	0.75
33	Sakandar	2.00
34	Gani Talukder	4.00
35	Mofiz Uddin	1.00
36	Nahi Mondal	3.00
37	Jasim Uddin	1.00
38	Hazrat Ali	3.00
39	Gani	2.50
40	Abdul Latif	2.00
41	Ayan Ali	1.50
42	Akram Hossain	2.00
43	Abdur Rouf	2.00
44	Siddique	1.50
45	Siddique(Jamal)	1.50
46	Mozibur	1.00
47	Shahid	3.00
48	Chanu	3.50
49	Kuddus	0.70
50	Koshimuddin	1.00
51	Shahidullah	2.00
52	Eunus Ali	1.50
53	Lebu	2.00
54	Salim	4.00
55	Jubed Kazi	20.00
56	Abul Hossain	3.00
57	Shahidul	5.00
58	Mannan Member	20.00
59	Shahidul, Tomej	20.00
60	Mohosin	4.00
61	Sirajul	5.00
62	Ashehaq Ali	20.00
63	Khurshed Alam	10.00
64	Nazrul	4.00
65	Haje Askar	3.00
66	Giash Uddin	15.00

67	Suruz	4.00
68	Kalmen	10.00
69	Hafej Mohammed	10.00
70	Moti	10.00
71	Nuru	3.00
72	Newaz Khan	5.00
73	Sirajul	5.00
74	Shushek Marma	5.00
75	Mannan	7.00
76	Shaiful	2.50
77	Abdul Alim	2.00
78	Tofazzal	10.00
79	Bulbul	2.00
80	Abul Hossain	6.00
81	Abdul Latif	5.00
82	Shawkat	5.00

Appendix – 3: Zero-Waste multiple uses of Jatropha

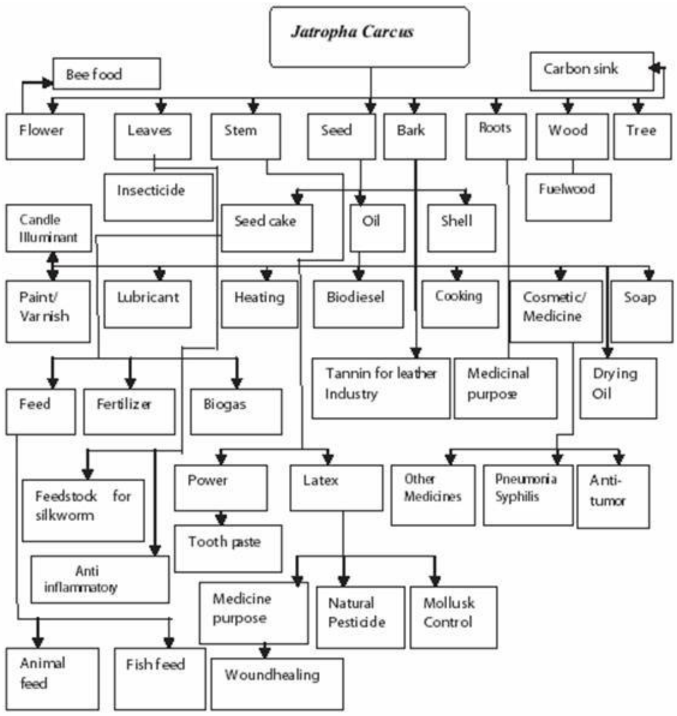

Figure 1. Chart showing the zero-waste use of Jatropha.

Table 1. Fatty acid composition of Jatropha oil (Gubitz et al, 1999)

Fatty acid %		
Myristic acid	14:0	0-0.1
Palmitic acid	16:0	14.1-15.3
Stearic acid	18:0	3.7-9.8
Arachidic acid	20:0	0-0.3
Behenic acid	22:0	0-1.2
Palmitoleic acid	16:1	0-1.3
Oleic acid	18:1	34.3-45.8
Linoleic acid	18:2	29.0-44.2
Linoleic acid	18:3	0-0.3

Table 2. Chemical, physical and fuel parameters of Jatropha curcas oil and methyl (ethyl) esters (Foidl et al., 1996)

Parameter	Unit	Jatropha carcus oil	Methyl esters of Jatropha oil	Ethyl esters of Jatropha oil
Density at 15°C	g/cm^3	0.920	0.879	0.886
Viscosity at 30°C	cSt	52	4.84	5.54
Flash Point	°C	240	191	190
Neutralization number	Mg KOH/g	0.92	0.24	0.08
Sulfated ash	% weight	-	0.014	
Cetane number		-	51	59
Contradson carbon residue	% weight	-	0.02	50.018
Methyl (ethyl) ester content	% weight	-	99.6	99.3
Monoglycerides	% weight	Not detected	0.24	0.55
Diglycerides	% weight	2.7	0.07	0.19
Triglycerides	% weight	97.3	Not detected	Not detected
Methanol	% weight	-	0.06	0.05
Water	% weight	0.07	0.16	0.16
Free glycerol	% weight	-	0.015	Not detected
Total glycerol	% weight	-	0.088	0.17
Phosphorus	ppm	290	17.5	17.5
Calcium	ppm	56	6.1	4.4
Magnesium	ppm	103	1.4	0.8
Iron	ppm	2.4	0.9	0.3

Table 3. Calorific value of Jatropha seed sample, extractable and fossil fuels (Augustusa, 2002)

Parameter	Calorific Value	
	(cal/g) (dry)	(MJ/kg)
Seed sample	4980.3	20.852
Oil fraction	9036.1	37.832
Hydrocarbon fraction	9704.4	40.630
Fuel oil from (Mexico)	10308.0	43.158
Crude oil (fossil fuel)	10531.0	44.091
Gasoline (fossil fuel)	11256.0	47.127

Table 4. Chemical composition (% in DM) of meals of Jutropha curcus varieties and soyabean meal (Makkar et al., 1998)

Item	Variety				
	Cape Verde	Nicaragua	Ife-Nigeria	Non toxic Mexico	Soybean meal
Crude protein	56.4-57.3	61.2	55.7	63.8	45.7
Lipid	1.5	1.2	0.8	1.0	1.8
Ash	9.6	10.4	9.6	9.8	6.4
Neutral Detergent fibre	9.0	8.1	8.9	9.1	17.2
Acid detergent fibre	7.0	6.8	5.6	5.7	12.2
Acid detergent lignin	0.4	0.3	0.1	0.1	0.0
Gross energy ($MJkg^{-1}$)	18.2	18.3	17.8	18.0	19.4

Table 5. Chemical composition of kernel, shell and husk of Jatropha curcas varieties (Makkar et al., 1998)

Item	Variety								
	Cape Verde		Nicaragua		Ife Nigeria			Non-Toxic Mexico	
	Kernel	Shell	Kernel	Shell	Kernel	Shell	Husk	Kernel	Shell
Dry matters analysis (%DM)	96.6	90.3	96.9	90.4	95.7	91.9	91.3	94.2	89.8
Crude protein	22.2	4.3	25.6	4.5	27.7	5.8	6.3	27.2	4.4
Lipid	57.8	0.7	56.8	1.4	53.9	0.8	1.1	58.5	0.5
Ash									
Neutral detergent Fibre	3.8	83.9	3.5	85.8	4.1	89.6	65.9	3.8	89.4
Acid detergent fibre	3.0	74.6	3.0	75.6	2.6	79.8	61.3	2.4	78.3
Acid detergent lignin	0.2	45.1	0.1	47.5	0.00	47.4	14.4	0.00	45.6
Gross energy MJ/Kg	30.7	19.3	30.5	19.5	29.7	19.5	15.6	31.1	19.5

Figure 2. Jatropha oil burning.

Table 7. Toxic and antinutritional components in the degreased meal of three different varieties of Jatropha (Makkar and Becker, 1997 in Gubitz et al, 1999)

Toxins	Units of measurement	Cape Verde	Nicaragua	Non Toxic Mexico
Lectin	Mg meal/ml which produced hemagglutination	102	102	51
Tryspin Inhibitor	Mg g^{-1} trypsin inhibited	21.3	21.1	26.5
Phytates	%	9.4	10.1	8.9
Saponins	% diosgenin equivalent	2.6	2.0	3.4

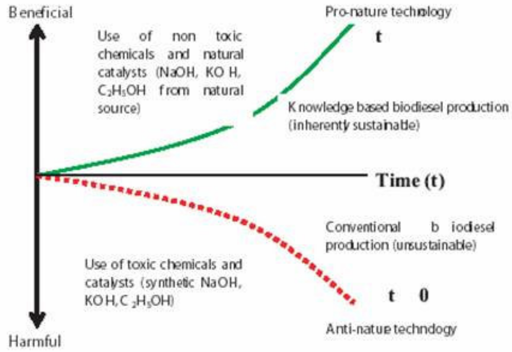

Figure 4. Sustainable biodiesel production from Jatropha (modified after Islam, 2004).